



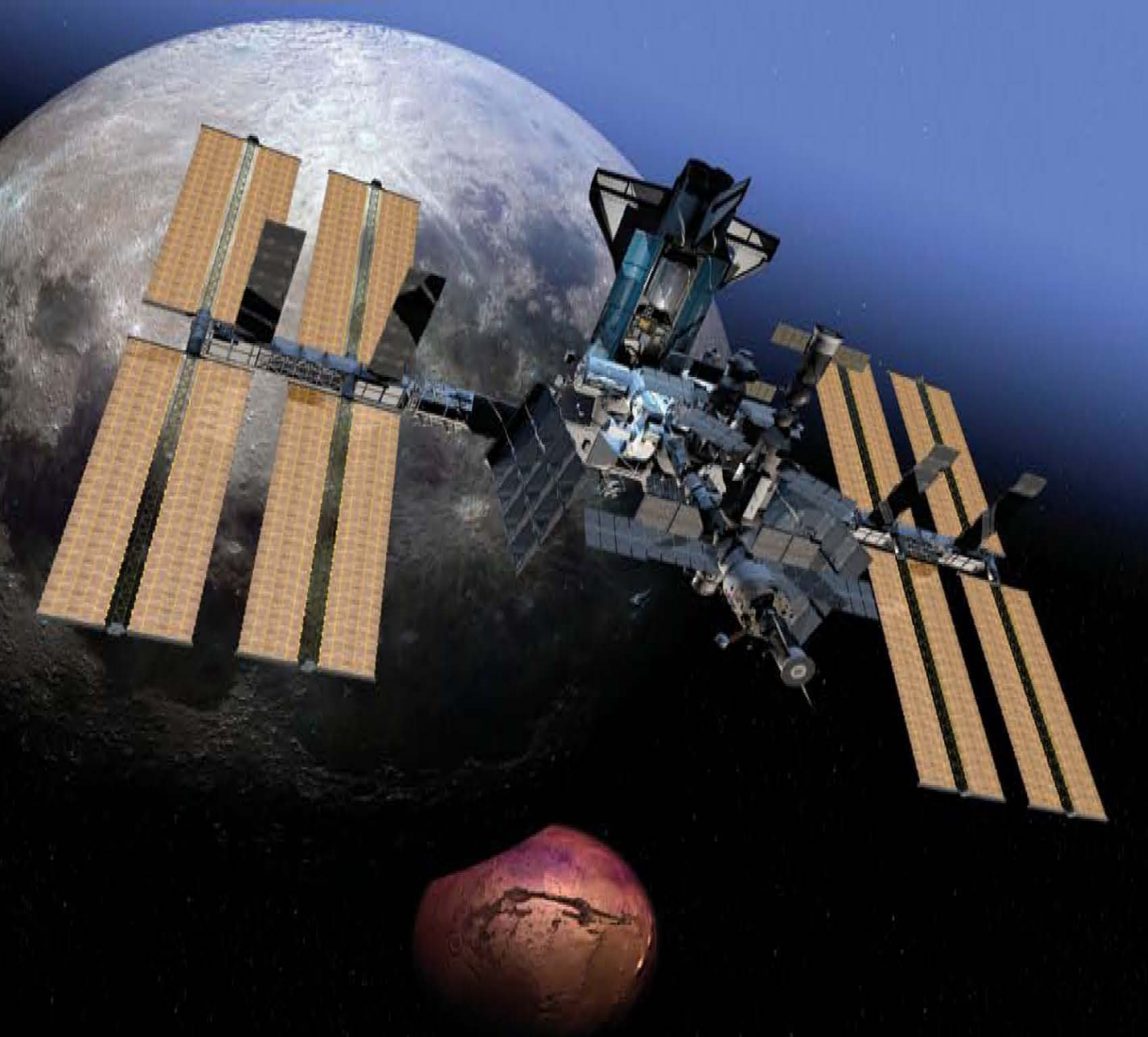
**Imagine** the Possibilities

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Mathematician • Inventor • Engineer

# International Space Station

NATIONAL LABORATORY EDUCATION  
CONCEPT DEVELOPMENT REPORT

December 2006



### **Acknowledgement**

I would like to express my gratitude to the interagency Task Force members, the consultants, and the advisors who have given so generously of their time and energy to support these first steps toward a new role for education on the International Space Station. I appreciate the patience that the group demonstrated in bringing together so many different perspectives from the participating Federal agencies to create this report. On behalf of the National Aeronautics and Space Administration, I would like to thank the participating organizations for allowing many senior personnel to take part in this effort. Finally, I would like to emphasize that participation by an agency in the development of this report does not imply any commitment of agency resources to the International Space Station National Laboratory.

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## Executive Summary

**The International Space Station (ISS) Program has brought together 16 spacefaring nations in an effort to build a permanent base for human explorers in low-Earth orbit, the first stop past Earth in humanity's path into space.**

The ISS is a remarkably capable spacecraft, by significant margins the largest and most complex space vehicle ever built. Planned for completion in 2010, the ISS will provide a home for laboratories equipped with a wide array of resources to develop and test the technologies needed for future generations of space exploration. The resources of the only permanent base in space clearly have the potential to find application in areas beyond the research required to enable future exploration missions. In response to Congressional direction in the 2005 National Aeronautics and Space Administration (NASA) Authorization Act, NASA has begun to examine the value of these unique capabilities to other national priorities, particularly education.

In early 2006, NASA invited education experts from other Federal agencies to participate in a Task Force charged with developing concepts for using the ISS for educational purposes. Senior representatives from the education offices of the Department of Defense, Department of Education, Department of Energy, National Institutes of Health, and National Science Foundation agreed to take part in the Task Force and have graciously contributed their time and energy to produce a plan that lays out a conceptual framework for potential utilization of the ISS for educational activities sponsored by Federal agencies as well as other future users. At this stage of planning, the participating agencies have not identified any funds for ISS educational projects, and their participation does not indicate any commitment of resources. Both their resource requirements and their funding sources are subjects for follow-on efforts.

The education and training of young people to take productive places in our society is of profound importance to the Nation. Failure to effectively prepare future generations to understand and participate in a complex world and a high-technology economy would bear directly on our national security and our future economic vitality. Though NASA's primary mission, as described in the National Aeronautics and Space Act of 1958, is centered on the science and technology of aeronautics and space exploration, NASA has long recognized the close coupling of its mission to education. Educational content has been an established component of NASA's ISS activities since the planning stages of the ISS, involving student-developed activities conducted aboard the ISS, students performing classroom versions of ISS experiments, students participating in ISS events involving engineering and operations activities, and crew-initiated informal educational demonstrations. To date, these projects, which are described in the NASA report *Inspiring the Next Generation: Student Experiments and Educational Activities on the International Space Station, 2000–2006*, have been estimated to involve over 31 million students. The report is referenced in this document.

The ISS National Laboratory Education Concept Development Report explores the potential of the ISS to support educational projects initiated by a variety of non-traditional users, including other Federal agencies. *The task group has concluded from its first phase of discussions that there is significant interest among other Federal agencies in the opportunity to further develop the ISS as an asset for education.* The group has produced a concept of operations



describing how Federal agencies and other organizations might economically use the ISS with minimal additional infrastructure. Although it was understood by the Task Force that hardware-oriented experiments are expensive to build and difficult to transport, it was also recognized that educational activities can take many forms that are far less resource-intensive. An analysis of the tasks required to conduct various types of education activities on the ISS is included in the full report.

In the course of its discussions, the group identified a number of project concepts that could be implemented by non-NASA users of the ISS under the auspices of a national laboratory. A key consideration for the Task Force is the timely execution of flight activities. The developmental periods characteristic of flight hardware

projects and the funding required to obtain launch services were seen by the Task Force as detrimental, in an educational context. Projects involving student interaction in flight activities, access to real-time imagery and communications resources, and pre-/post-launch space flight event attendance may offer effective and economical alternatives.

This report is the first phase in the planning of an educational project for the ISS as a national laboratory. It is anticipated that following the review of this report and the receipt of further direction from government policymakers, the Task Force will proceed to develop a detailed plan for the implementation of an education project, including a management plan for the use of ISS resources and the growth of educational activities.



*Figure 1. The International Space Station*



# Introduction

## PURPOSE

The United States' segment of the International Space Station has payload resources and accommodations that exceed the requirements for planned NASA missions for space exploration. The objective of this concept development plan is to examine the feasibility of and develop a strategy for the use of available ISS resources and accommodations as a venue to engage, inspire, and educate students, teachers, and faculty in the areas of science, technology, engineering, and mathematics (STEM). Under the ISS National Laboratory, ISS resources will be managed as a national education center accessible to teachers, students in kindergarten through post-doctoral studies, and university/college faculty.

## BACKGROUND

### The International Space Station

The International Space Station (Figure 1) is the largest international scientific project in history. Led by the United States, the International Space Station draws upon the scientific and technological resources of 16 nations, including Canada, Japan, Russia, and nations of the European Space Agency, to create and operate the world's only continuously inhabited outpost and laboratory in space. The ISS will be completed over the next 4 years. The focus of the ISS National Laboratory effort is to ensure that the unique capabilities of this national investment are effectively utilized.

More than four times as large as the Russian Mir space station, the completed International Space Station will have a mass of about 420,454 kilograms (925,000 pounds). It will measure 110 meters (361 feet) across and 74 meters (243 feet) long, with almost an acre of solar panels to provide electrical power to six state-of-the-art laboratories.

The Station will be in an inclined orbit of 51.6 degrees and at an altitude of 402 kilometers (250 miles). This orbit allows the Station to be reached by the launch vehicles of all the international partners to provide a robust capability for the delivery of crews and supplies. The orbit also provides excellent Earth observations, with coverage of 85 percent of the globe and 95 percent of populated areas. At the end of the year 2006, about 227,273 kilograms (500,000 pounds) of Station components were on orbit.

Research requiring pressurized conditions will be conducted primarily in the U.S. Laboratory Destiny, the European Columbus Module, the Japanese Experiment Module (JEM), and the Russian Space Agency (RSA) research module (planned). Within these modules, refrigerator-sized racks are allocated for experimentation. These racks are called International Standard Payload Racks (ISPRs) and they provide a common set of interfaces, regardless of location.

Experiments that require exposure to the unpressurized environment may be mounted on the U.S. Truss and Express Logistics Carrier (ELC), the Japanese Exposed Facility (JEF), or the Columbus Exposed Facility (CEF). Hardware descriptions, designs, and photos for pressurized and unpressurized experimentation are found in Appendix A.

## Statement of the Problem

The people of the Nation are aware that we face a critical shortage of young people entering STEM careers. The Report of the President's Commission on Implementation of United States Space Exploration Policy, June 2004, states that, "the workforce required for the United States to prosper as a nation is not being trained adequately. Our current level of achievement in science and technology relative to other countries places America at risk economically and from a national security perspective."

It is a fact that graduate enrollment in aerospace engineering declined steadily in recent years—from 4,036 in 1992 to 3,485 in 2001—suggesting a diminishing interest in that career field (National Science Foundation/Division of Science Resources Statistics, "Graduate Enrollment Increases in Science and Engineering Fields, Especially in Engineering and Computer Sciences," NSF-03-315, April 2003). It is also true that more than half of all engineering doctoral degrees awarded by U.S. engineering colleges are to foreign nationals (National Science Board, Science and Engineering Indicators, Volume 2, Appendix Table 2–28: 2004). It is important that our country maintain an adequate supply of well-trained STEM workers.

This shortage impacts our ability to sustain economic vitality, technological leadership, and security. Americans are seeing the initial effects of a change in our leadership status. U.S. workers now compete for high-skill STEM jobs with workers around the world and must be prepared to work in a global environment.

Kendall Starkweather, Executive Director of the International Technology Education Association (ITEA), believes that past legislation leaves out the "T and E" of STEM. Few initiatives emphasize the impact of technology and engineering deficiencies on society. This is a classical error of thinking that math and science covers STEM. In practice, math and science teachers are

not teaching technology or engineering. In the end, the students are the ones who miss out.

With strong bipartisan support, a series of bills was introduced in January 2006 in the U.S. Senate with endorsements by members of the U.S. House of Representatives. These legislative initiatives, collectively referred to as Protecting America's Competitive Edge (PACE), focused on energy, education and research, and financial tax incentives and appeared in response to the National Academies' *Rising Above the Gathering Storm* report. Also in January 2006, President Bush announced the American Competitiveness Initiative (ACI) in his State of the Union Address. The PACE and ACI initiatives coupled with the growing national discourse on increasing the American student's focus on science, technology, engineering, and mathematics education point toward a common goal for the executive and legislative branches of improving STEM literacy.

## The ISS National Laboratory: A Designated Resource for Education

Utilizing the International Space Station National Laboratory for education is an effort initiated in response to the 2005 NASA Authorization Act, which designated the U.S. segment of the ISS as a national laboratory and directed NASA to develop a plan to "increase the utilization of the ISS by other Federal entities and the private sector through partnerships, cost-sharing agreements, and any other arrangements that would supplement NASA funding of the ISS."

Following NASA's decision to focus ISS research on requirements for space exploration, space capabilities previously unavailable are now being offered for education. Approval of this project gives teachers, faculty, and students of every age access to the space environment and an opportunity to engage in space research at affordable prices.

The Nation can use an existing resource—the ISS—and the uniqueness of space to energize STEM education in the United States. The ISS National Laboratory will take advantage of available resources to develop the workforce and stimulate scientific and technical innovations in the United States. Where else can a 12 year old demonstrate the robustness of a robot design or compare the growth time, quality, and weight of produce harvested in space?



NASA will scale up current educational uses of the Station, expanding upon the activities that most effectively inspire, engage, and educate. All astronauts can and do teach from space, and those teachers can reach many minds. A nation of children can join an astronaut for a variety of stimulating learning opportunities. NASA can offer space-related laboratory experiences that have not been offered in its history to Kindergarten–12 (K–12) students. The ISS National Laboratory Project, hereafter called the Project, can design and expand the opportunities for researchers at the university level. Students will be a virtual “arms-length” from astronauts, research lockers and racks, the Moon, Mars, other planets, asteroids, and beyond.

Using the ISS National Laboratory as a venue and using space travel and exploration as the education media, the Project will select premiere STEM-relevant curricula, tools, hands-on activities, and teaching techniques from all available sources to stimulate the interest and enhance the quality of education in science, technology, engineering, and mathematics. In an organized, systematic manner, the Project will make these resources, including space data, available everywhere: in public schools in the mountains of Appalachia; in reservation schools; in preparatory schools in Washington, DC; in the home for parents who homeschool their children; in parochial schools; and in museums and planetariums around the United States. The Project can make space data available to researchers at all grade levels. Partnerships with nontraditional organizations such as bulk distribution centers, grocery stores, faith-based facilities, as well as the media (TV, newspapers, etc.) will be explored to enhance student outreach. The Project can give students real and virtual access to astronauts in space. The Project can connect students with space and data systems experts whose role is to engage, inspire, and educate.

Regular and pervasive use of orbiting space vehicles as a venue to educate has not been an emphasis to date because of cost (benefit vs. cost). Access to space is expensive; space venues can be daunting; and preparations for transporting instruments to space are complex, time-consuming, and expensive. It is not difficult to understand why educating from a space environment at this time is rare. Now that the ISS has been designated a national laboratory, the idea of using the world’s largest space vehicle for education is intriguing.

Currently, it takes an average of 5 to 7 years to prepare a project for launch, and another 1 to 2 years for project completion. This duration is too prolonged to meet a typical graduate researcher’s matriculation guidelines. It does not come close to meeting the needs of the classroom teacher, who generally has access to students for only 1 year. Designers of activities for student participation must consider elementary, secondary, and graduate school cycles. Streamlined processes are needed to better align with academic matriculation requirements.

The International Space Station is by far the most capable space vehicle ever built. Because of the complexity of its design and operations, educators have found it time-consuming, even challenging, to develop and deliver age-appropriate material for the spectrum of users desired. With more and more educators engaged in space studies, and with industry, the Federal government, and nonprofits taking a leadership role in education, the education community can expect (1) increased partnerships and collaborations in the development of STEM-relevant material for education, (2) targeted assistance in understanding the complexities of space travel, and (3) greater sharing of data, products, facilities, and individuals connected to space-related programs.

Structured and focused STEM education correlated to student performance will produce the skilled workforce required for the U.S. to prosper as a nation. However, the ISS National Laboratory Project is just one instrument in the Nation’s arsenal. It will take many focused efforts to maintain our position of technological pre-eminence in the world.

**Why are NASA and the ISS National Laboratory critical in stimulating youth to pursue careers in science and technology, contributing to the U.S. government’s need for a skilled workforce, and leveraging the interests of students of all ages?**

The President’s Commission on Implementation of United States Space Exploration Policy unequivocally recognized NASA’s critical role in inspiring the next generation of explorers. Exploration in space clearly captures the interest and imagination of both children and adults. Many of today’s leading scientists and engineers were

inspired by the Nation's successful Apollo program, yet the United States now faces a critical shortage of young people entering into science and technology careers. The challenge is to leverage the journey to the space frontier to develop the Nation's long-term STEM workforce.

The ISS National Laboratory is a symbol of an advanced technological world. It represents the future, much the same as the Enterprise in the *Star Trek* series. As a national laboratory, the ISS has sufficient accommodations and resources to meet NASA's needs for exploration mission research, as well as to contribute to the broader U.S. government need for developing and training a domestic workforce in science and technology.

NASA and the ISS National Laboratory:

- Provide an extraordinary opportunity to stimulate mathematics, science, and engineering excellence for America's teachers and students and to engage the public in a journey that will shape the course of human destiny;
- Leverage the excitement of space research as a banner to focus on training the workforce and engaging learners of all ages;
- Utilize partnering across Federal, State, local, and private sectors to sponsor scholarships, internships, on-the-job training, and to establish a shared education vision;
- Collaborate extensively with educators in the Federal government, specifically the Department of Education and the National Science Foundation; and
- Seek new and innovative educational concepts, curricula, and certification programs supported by government, industry, and academia.

From past experience, the NASA Office of Education knows that the study of space is of interest to students. As we look at student access to NASA Web sites and attendance at space-related movies and as we listen to teacher testimonials, we have confidence that space will attract student interest. Once engaged in the ISS National Laboratory, students will have access to a multitude of educational resources and opportunities.

### International Involvement in the ISS National Laboratory Project

The ISS in many ways represents the pinnacle of modern scientific and engineering achievement. What is most interesting about this achievement is that no one nation

alone could have succeeded in bringing this vision to fruition. The success of the ISS is an international success and a marvelous example of the potential that lies in human cooperation.

The National Academies report *Rising Above The Gathering Storm* recommends that we include the best and brightest students in science and engineering higher education programs. Recommendation C specifically says: "Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world." Although many of the Committee on Prospering in the Global Economy of the 21st Century's (hereafter called the Committee on Prospering) actions suggest increasing U.S. citizen STEM education pursuits, it resoundingly paves the way for bright international students to study, earn degrees, and become employed in the U.S.

Norman R. Augustine, retired Chairman and Chief Executive Officer of the Lockheed Martin Corporation, stated before the Science Committee of the U.S. House of Representatives in October of 2005 that, "America today faces a serious and intensifying challenge with regard to its future competitiveness and standard of living. Further, we appear to be on a losing path. . . . Human capital—the quality of our work force—is a particularly important factor in our competitiveness. Our public school system comprises the foundation of this asset. But as it exists today, that system compares, in the aggregate, abysmally with those of other developed—and even developing—nations . . . particularly in the fields which underpin most innovation: science, mathematics, and technology."

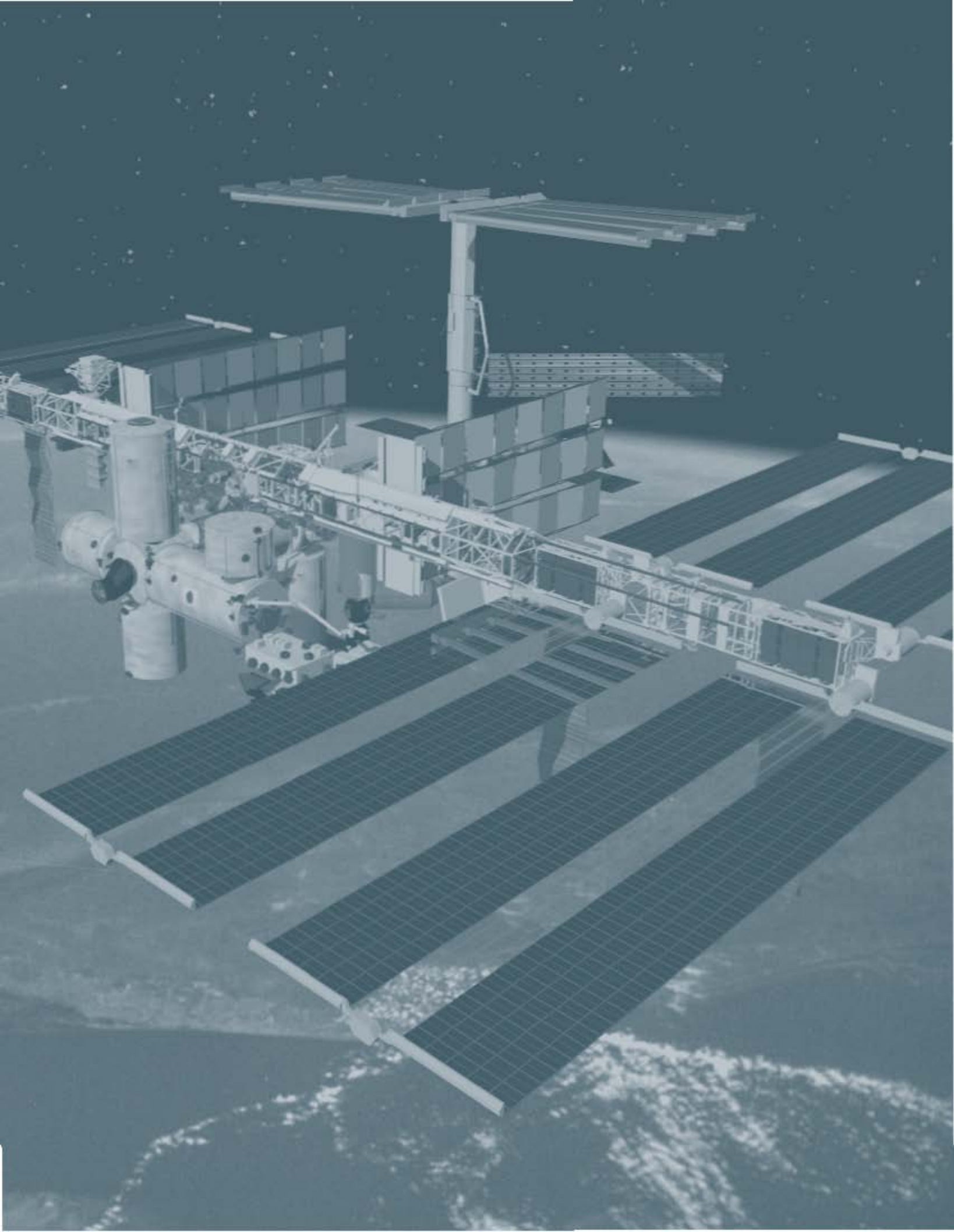
The primary function of the ISS National Laboratory should be to improve interest in, and the quality of, STEM education in the United States. However, like many of the challenges faced in the development of the ISS, the Task Force senses that the response to this challenge will need to be one that involves international cooperation. The United States can no longer afford a Cold War vision of its educational system as being separate from, and in competition with, the rest of the world. In order to confront the challenges it will face in the 21st century, the education system, much like the ISS project, will need to function in an environment of international cooperation.

While the Task Force's primary aim should be to improve the quality of American education, it is also important to consider the benefits of international cooperation in pursuing this goal aboard the ISS National Laboratory. The ISS National Laboratory Project is an opportunity to unify peoples from around the world, and possibly allow all American students to engage in international projects, rather than separate countries further. To be successful in the 21st century, American students must learn to work in an international environment. Just as with the ISS, students can accomplish more by working together than they can in competition with each other. America may even find, to our surprise, that together our efforts are synergistic.

Support for inclusion of international students in the ISS National Laboratory Project is widespread. Teachers, educators in the Federal government, and Task Force members all support the inclusion of bright and energetic students in the project, regardless of origin. However, the level of international student involvement is predicated on the policies and statutes of the sponsoring Federal agency. This point is critical. Decisions regarding international student participation, whether as a team member or principal investigator, are made by the sponsoring Federal agency. Sponsoring agencies are ultimately responsible for ensuring that education programs and projects comply with all U.S. export control laws and regulations.









## National Reports, Studies, and Activities

### What's been done before?

Numerous papers have been written, studies performed, and activities demonstrated to determine how students learn STEM subjects and how they are progressing on the continuum toward STEM employment. Jack Jekowski of Innovative Technology Partnerships, LLC, summarized all major reports and studies pertaining to math and science education in the past 13 years (See Figure 2 and Figure 3). The reports have the same theme—the Nation is at risk, we must take action, we are failing in math and science. Implied, but not explicitly stated, is the fact that the Nation is also failing to achieve its potential in technology and engineering.

Select education methods and materials are achieving the desired results, but not in sufficient quantities. Below is a summary of some of the most successful activities. Activities include both teacher and student preparation.

**Intel® Teach to the Future** (<http://www97.intel.com/education/teach/>) is a worldwide effort to help both experienced teachers and preservice teachers integrate technology into instruction to develop students' higher-order thinking skills and to enhance learning. Participating teachers receive extensive instruction and resources to promote effective technology use in the classroom.

Teachers learn from other teachers how, when, and where to incorporate technology tools and resources into their lesson plans. In addition, they experience new approaches to create assessment tools and align lessons with educational learning goals and standards. The program incorporates use of the Internet, Web-page design, and student projects as vehicles to powerful learning.

Launched in 2000, Intel Teach to the Future has trained more than 3 million teachers in over 35 countries. Countries currently participating in the program include: Argentina, Australia, Austria, Brazil, Chile, China (People's Republic of), Colombia, Costa Rica, Czech Republic, Egypt, Germany, India, Ireland, Israel, Italy, Japan, Jordan, Korea, Malaysia, Mexico, Pakistan, Philippines, Poland, Portugal, Russia, South Africa, Switzerland, Taiwan, Thailand, Turkey, Ukraine, the United States, and Vietnam. Intel often collaborates with ministries of education or other government entities to adapt the curriculum for each location.

**Project Lead the Way (PLTW)** (<http://www.pltw.org/aindex.htm>) has developed a 4-year sequence of courses which, when combined with college preparatory mathematics and science courses in high school, introduces students to the scope, rigor, and discipline of engineering and engineering technology prior to entering college.

The courses are:

- Introduction to Engineering Design
- Digital Electronics
- Principles of Engineering
- Computer Integrated Manufacturing
- Civil Engineering and Architecture
- Biotechnical Engineering (in development)
- Aerospace Engineering (in development)
- Engineering Design and Development

## NEW MEXICO PARTNERSHIP FOR MATH AND SCIENCE EDUCATION

### A Sample of Major National Reports on the Math and Science Crisis

**A Nation at Risk:**  
**The Imperative for**  
**Educational Reform**  
 A Report to the Nation  
 and the Secretary of Education  
 United States Department of  
 Education  
 by  
 The National Commission on  
 Excellence in Education  
 April 1983

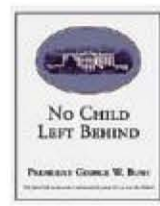
A Nation at Risk  
 (April 1983)



The Glenn Commission  
 (September 2000)

**Road Map for**  
**National Security**  
**Imperative for Change**  
 The Phase III Report of the U.S.  
 Commission on National Security  
 21st Century  
 The United States Commission on  
 National Security/21st Century  
 February 15, 2001

The Hart-Rudman Com-  
 mission (February 2001)



No Child Left Behind  
 (January 2002)



Betraying the College  
 Dream (March 2003)



Keeping America  
 Competitive (April 2003)



U.S. Dept. of Education  
 Math & Science Initiative  
 (May 2003)

1983–1999

2000

2001

2002

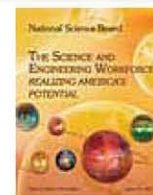
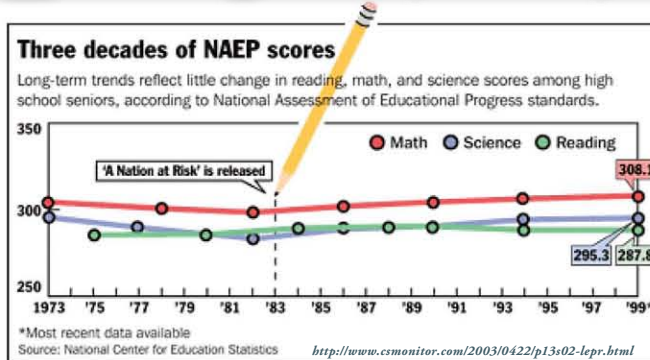
2003



Project 2061 Science  
 for All Americans  
 (AAAS 1989)



Baldrige Education  
 Criteria  
 (First Published in 1995)



National Science Board  
 The Science and  
 Engineering Workforce  
 Realizing America's  
 Potential  
 (August 2003)



Understanding University  
 Success (2003)

Figure 2. National Reports, Studies, and Activities Part I

Introduction at this level will attract more students to engineering and will allow students, while they are still in high school, to determine if engineering is the career they desire. Students participating in PLTW courses are better prepared for college engineering programs and more likely to be successful, thus reducing the attrition rate in these college programs, which currently exceeds 50 percent nationally.

A critical component of the Project Lead The Way program is its comprehensive teacher-training model. The curriculum these teachers are required to teach utilizes cutting-edge technology and software requiring specialized training. Ongoing training supports the teachers as they implement the program and provides for continuous improvement of skills.

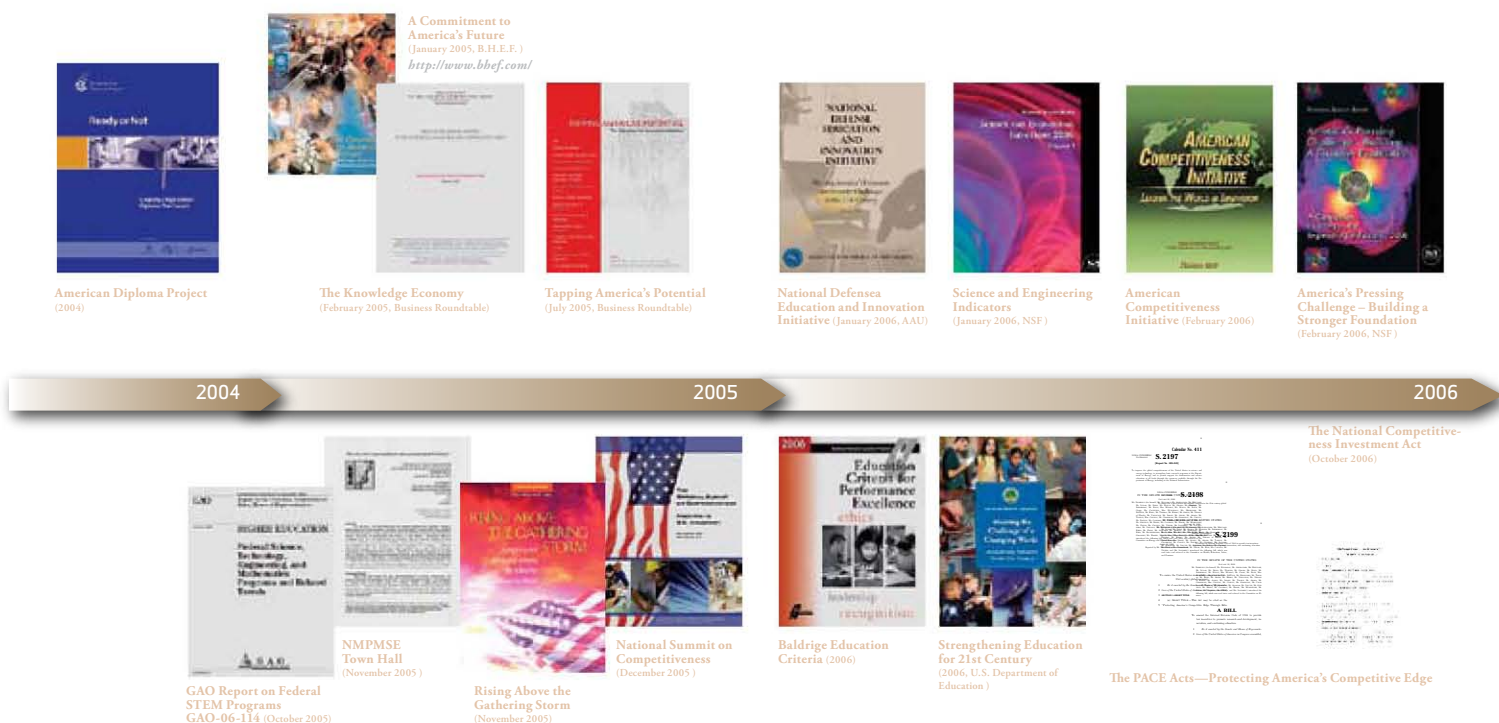
Merck & Co., Inc. founded the **Merck Institute for Science Education** (MISE) (<http://www.mise.org/misel/index.jsp>) in 1993 with the mandate to improve student performance and participation in science. The company sought to wed children's curiosity and enthusiasm for learning with an investigative approach to science. The

Merck Institute is moving from vision to reality by:

- Deepening current and future teachers' knowledge of science and education;
- Providing access to exemplary curriculum materials;
- Encouraging assessment of student learning aligned with and informing instruction;
- Organizing and providing resources to support the science efforts of teachers, administrators and community members; and
- Supporting policies at the local, State and national levels that promote science education.

Focusing on students in kindergarten through eighth grade, the Institute seeks to nurture children's curiosity through investigations of key scientific concepts. The hallmark of the Institute's work is the establishment of vital partnerships with educators, parents, Merck employees, and policymakers. Soon after its inception, the Institute formalized partnerships with four school districts located next to Merck's major facilities in New Jersey and Pennsylvania. These partnerships have





**Figure 3. National Reports, Studies, and Activities Part 2**

provided the context for much of the Institute's work. The product of this work is science teaching and learning that parallels the methods of inquiry scientists use to investigate the natural world. The Merck Institute's ultimate goal is to improve student performance and participation in science.

The challenge now facing the Institute is to leverage the success of these efforts so that increasing numbers of classrooms throughout the country become centers of standards-based teaching and learning. Based on the lessons it has learned about education reform and the power of collaboration, MISE will continue to build partnerships to improve student performance and participation in science until high-quality science education is indeed the standard for all children.

The **Lockheed Martin Academy/UCF for Mathematics and Science** (LMA) (<http://lockheedmartin.ucf.edu>), established in 1992, is a collaborative effort of the Lockheed Martin Corporation with the University of Central Florida. LMA involves two distinct programs. One is focused on improving performance in

mathematics and science by improving the ability of K–8 teachers to teach these critical areas. The second is a program that prepares professionals from STEM careers and STEM majors to transition into teaching mathematics and science in the critical middle school years. Nearly 400 teachers have had master's-level experiences within these programs. In 2004, the American Association of State Colleges and Universities (AASCU) awarded LMA the prestigious Christa McAuliffe Award for excellence in teacher education.

The University of Pennsylvania (Penn) School of Arts and Sciences departments of Biology, Chemistry, Earth and Environmental Science, Mathematics, and Physics, in collaboration with the Graduate School of Education (GSE), is establishing the **Penn Science Teachers Institute** (Penn STI) (<http://www.sas.upenn.edu/PennSTI/>) in a major effort to engage in the development and retention of highly qualified science teachers in middle and secondary grades. The Penn STI, managed through the Department of Chemistry, provides content-intensive master's degree programs for developing content, pedagogy, and leadership skills for science

teachers. This Institute is aimed at 20 area schools/districts in the mid-Atlantic region and includes four major components:

- 1) An 8-science content/2-science education course Master of Integrated Science Education degree program designed for current middle-level science teachers;
- 2) An 8-chemistry/2-science education course Master of Chemistry Education degree program designed for current high school science teachers;
- 3) A resource center supporting participating teachers and those who have completed the program as they become teacher leaders and implement classroom reforms in their schools; and
- 4) An Administrator's Science/Math Academy designed for school administrators to help them become better prepared to create a school environment conducive to improved science teaching and learning.

Up to 100 middle-level science teachers and 100 high school science teachers are expected to participate in the degree programs, along with approximately 200 school administrators. The 200 science teachers who graduate from the content-intensive programs, supported by their administrators and a university-based resource center, are expected to fundamentally change the teaching and learning of science in middle- and secondary-level classrooms in the region, benefiting the learning of science by tens of thousands of students annually.

The International Technology Education Association's Center to Advance the Teaching of Technology and Science has developed a standards-based K-12 solution called **Engineering byDesign™** (EbD™). The articulated sequence of courses is based on the Technology (ITEA), Science (AAAS), Mathematics (NCTM) and Engineering (NASDCTE) standards, and is focused on the teaching of STEM through Technology, Innovation, Design, and Engineering (TIDE) for all students. The sequencing of courses was developed using research-based methods,

and the courses themselves were developed using the Backwards Design Model (Wiggins & McTighe).

The EbD program uses integrated units and lessons at the K-2 and 3-5 grade bands to deliver the concepts of engineering and the engineering design process. Building on these concepts and skills, students at the middle school focus on exploring how technology can influence their lives, how invention and innovation are critical to improving the humanmade world, and how the core components of technology are combined to form systems. The high school component further focuses on the designed world, the issues and impacts of technology, and the transfer of technology applications throughout society. As the capstone course, Engineering byDesign engages students in high-level engineering concepts and applications as they work in engineering design teams to design solutions to rigorous contextual problems. A number of the courses have units developed through projects funded by NASA, and two of the courses were developed with funding through the National Science Foundation (NSF). In addition, lessons and units at the elementary level were developed with funding from NASA and NSF.

A consortium of States is implementing the program nationally, and the teachers delivering the courses participate in the Engineering byDesign network. This community of learners connects teachers across the country to each other to share resources, compare and contrast student work, and to collaboratively solve curricular challenges.

Clearly America is on the right track. Academia, industry, and private interests are all trying different methodologies to stop the "brain drain." The ISS National Laboratory Project has been initiated and has great potential for accelerating these efforts using the best processes, exciting material, and strong partnerships to accomplish the Nation's education and workforce goals.



## ISS National Laboratory Concept of Operations

### ISS National Laboratory Education Allocation

The International Space Station U.S. National Laboratory will have approximately one-half of the ISS/U.S. utilization capability available for its use. An allocation of ISS resources (crew time, power, data downlink, etc.) and accommodations (on-orbit volume, Express Rack space, etc.) will be dedicated to the education community for education payloads and activities. This allocation will represent a minimum amount of the available excess ISS capacity (based on a per-year average).

### ISS National Laboratory Utilization Planning

An ISS Education Coordination Working Group (IECWG) will be established and composed of representatives of any Federal agency having an interest in using the ISS National Laboratory. The working group members will represent their Federal agencies in working group planning activities and will be responsible for soliciting, selecting, and submitting education payload and/or activity recommendations to the IECWG in support of the ISS National Laboratory payload manifesting process. Federal agencies will serve as sponsors of education payloads and activities.

The IECWG will perform an initial review of requests from sponsoring organizations proposing education payloads for particular ISS “increments.” An increment is a 6-month period determined by arrival and departure of U.S./international partner crewmembers. The IECWG will prioritize the education payload manifest requests and then submit these requests into the ISS National

Laboratory manifesting process (process is under definition). The IECWG will also establish and keep a strategic plan of potential education payload candidates for the next 5 years of ISS increments.

Federal agencies may seek industrial sponsorships. All Federal agencies involved will broadly communicate the need for industrial partnership/sponsorship of ISS education payloads.

### Payload Candidate Types

The IECWG members/Federal agencies will be encouraged to develop portfolios of operations and/or packaging or grouping of experimentation. Combining multiple experiment or education activities in a single launch package will optimize the ISS education payload opportunities and minimize the requirements for ISS resources (crew time, power, data downlink, etc.) and accommodations (on-orbit volume, rack space, or external sites). In addition, packages combining multiple education activities will simplify the integration and operations support requirements, and will overall reduce education sponsor costs.

Examples of these packages include specialized Express Sub-Racks (one to four Middeck Locker equivalents) containing multiple types of equipment and demonstration items, coordinated onboard/ground-ops events, interactive audio/video (with and without crew involvement), mentor sessions, digital-automated or crew-supported photography, external automated experiments (similar to the Shuttle Get-Away Special [GAS] canisters), standard satchels, etc.



The development and manifesting of an EDPackage is an example of packaging multiple education activities for experimentation aboard the ISS. To accommodate an EDPackage, the ISS National Laboratory Project would allocate an International Standard Payload Rack for educational uses. The rack is filled with education-related materials and equipment. Teachers and students propose on-orbit experimentation using the materials and equipment. Two sequential steps are required to complete the activity. First, identify and place equipment on orbit, and second, solicit, select, and conduct experiments.

- **Identify and place equipment:**  
Convene a committee of nationally recognized educators every 1 to 3 years to design new subrack modules (1 to 4 modules) of equipment to be placed on orbit. Sources for such educators could include Presidential Award Winners, Albert Einstein Fellows, and the Teacher Advisory Council of the National Academy of Sciences. Kits could focus on specific content areas, (i.e., Physical Sciences, Biological Sciences, Earth/Space Science). Kits could be rotated on- and off-orbit on a regular schedule.
- **Solicit, select, and conduct experiments:**  
Solicit proposals from educators and/or students. Solicitations would be requested via several national organizations such as NSTA, AAAS, or the Federal government. IECWG members and Federal agencies would select education experiments. Astronauts would conduct experiments using the EDPackage equipment currently on orbit in the rack.

The advantages to this program are limited use of up and down mass and relatively quick turnaround of experimental results (less than 6 months), making such projects usable by teachers within a given school year with the same group of students.

Transportation to the ISS and regularly scheduled crew time are needed to successfully carry out this activity.

## Payload Integration and Operations

The education user/sponsor is responsible for unique payload integration activities. These activities include working with the assigned payload integration manager

to develop a payload interface agreement and a payload verification/test plan and to provide various other data required to certify that the payload is ready for flight, installation, and operation on the ISS. The user/sponsor is responsible for generating payload safety data packages, overseeing all payload integration and testing activities at the launch site or elsewhere, funding any unique testing required, providing training hardware and payload procedures, and supporting real-time payload operations on board.

## User/Sponsor Funding and Costs

Each user/sponsor organization will be responsible for funding the payload development, integration, and operations activities/requirements, which are required beyond the standard payload services provided by NASA and the International Space Station program. The basic ISS payload integration and operations support infrastructure (people and facilities) required to support the ISS National Laboratory payloads will be provided by NASA and the ISS Program as cost-effective extensions of other NASA payload support.

NASA and other participating Federal agencies will be included in the functions and costs associated with the operation of the ISS Education Coordination Working Group. The functions covered include meeting planning and secretarial support; generation and publication of reports; and the funding of special consultants or participants, as the IECWG determines appropriate and necessary.

The user/sponsor is also responsible for funding the cost of transportation to the ISS, using U.S. commercial launch and orbital transfer vehicles; the European Space Agency's Automated Transfer Vehicle; the Japanese HII Transfer Vehicle; and the Russian Progress vehicles. NASA will collect from launch vehicle owners the projected costs of flying a payload on each launch vehicle going to the ISS (i.e., the cost of each vehicle's standard payload launch service) and the launch vehicle payload opportunities covering the 2-year period ahead. This data will be provided periodically to ISS National Laboratory education payload sponsors or potential sponsors.



## 21st-Century Thinking on Education

### PROJECTS/ACTIVITIES FRAMEWORK

The education community continues to study models of learning and develop new instructional approaches to improve STEM education in the United States. The Nation's spending in education per student is among the highest in the world, yet the results are sometimes not commensurate with the investment. Clearly, there are many highly successful schools and students in the United States. Students from our college preparatory schools, gifted and talented schools, and magnet schools rank with the best in the world, but many others slip through the educational system without achieving their potential.

Through cooperative efforts with the Federal government, the Task Force has devised a framework that will help us identify excellent projects to enhance STEM literacy. These projects utilize methodologies such as hands-on applications, immersive-learning, integrated technologies, critical thinking, and mentoring.

The framework uses a traditional systems approach of inputs, processes, and outputs. NASA contributes the inputs (materials and resources) for study. Many educators say that space is a subject for which young people never seem to lose interest. The Federal government plans to use the students' curiosity and interest in space and the ISS to increase STEM literacy in the United States.

ISS data and information will be used as resources (inputs) for learning; NASA-unique people and facilities are instruments and tools used to enhance learning, and knowledge, skills, and understanding are outputs of learning.

The ISS National Laboratory will adopt NASA's framework to assess the quality of project portfolios and to ensure that all elements of the pipeline are involved. The framework allows the ISS National Laboratory Project Manager to monitor student participation at various experience levels. The community may use ISS resources and inventive programming to inspire, engage, educate, and employ students. Appropriate technology and other accommodations will be provided for students who cannot access the tools, materials, and hands-on activities in their traditional formats.

The ISS IECWG will use the framework described in Figure 4 to characterize activities that should be performed as part of the ISS National Laboratory Project. The framework applies to all STEM fields. Curriculum, instruction, instructional assessment, professional development, and student-based research and analysis are critical elements in any education framework. These five elements are the means by which the community educates the populous, whether in the classroom, in the home, or in the library. Project Lead the Way and Engineering byDesign both introduce new curricula and hands-on activities to enhance STEM literacy. These are "educate" activities. Before the education process begins, the community must inspire and instill in students the desire to learn. Astronauts travel across the United States speaking to students about the importance of studying. This is an "inspire" activity. Next, the community capitalizes on a student's yearning for knowledge with hands-on activities that excite and engage their interest. As many as two

million students compared basil seeds exposed to space with control seeds that remained on the ground in a project designed to evaluate the durability of materials exposed to the extreme environment of space. The High School Students United with NASA to Create Hardware (HUNCH) fabricates products that will be used at NASA. Thousands of students continue to photograph and observe fascinating features Earth as participants in the Earth Knowledge Acquired by Middle School Students (EarthKAM) program. These are “engage” activities. Along with academic training, advanced students are prepared for successful employment with special training that simulates on-the-job activities. Cooperative education programs where students work and go to school are “employ” activities.

If NASA uses the framework effectively, the result will be student populations at predictable levels of learning—knowledge, skills, and understanding. The desired

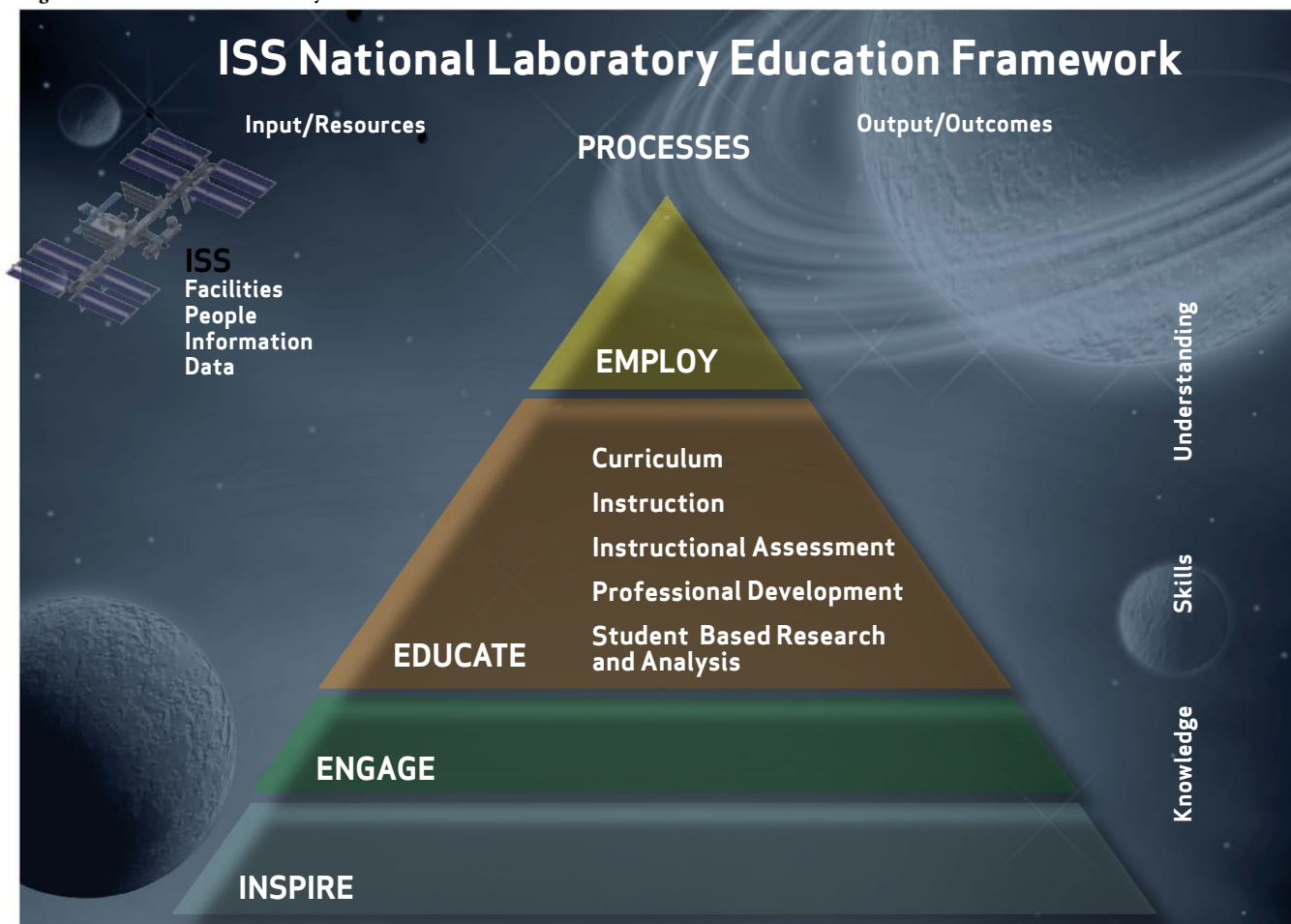
outcome is a student population in a measurable pipeline of STEM learning and an informed citizenry prepared and ready to participate in a complex, high-technology world.

The ISS National Laboratory Project Manager will continue to evaluate the projects and activities using the ISS National Laboratory resources to ensure the effectiveness of learning.

## EDUCATION METHODOLOGIES

The Nation’s goal is to improve the quality of STEM education as well as the number and diversity of students receiving the education. Ronnie Lowenstein, President of the Education Technology Think Tank says, “Current education paradigms and structures are incompatible with the social and economic realities our nation faces. Our education challenge is ‘To Innovate or

Figure 4. ISS National Laboratory Educator Framework





Abdicate our Competitive Edge.’ Education not only is tied to economic empowerment and the eradication of poverty, but it is fundamental to our national security. Quality education is a civil right! Ensuring an adequate education for all students requires establishing opportunities to learn conditions that engage youth, promote 21st-century skills of inventing, thinking, and inspiring their aspiration, as well as achievement. To achieve equitable learning opportunities throughout America requires both innovative policies and reflective educational practices grounded in research. Individually and collectively, we have both an opportunity and a moral obligation to address the issues that will ensure educational and economic empowerment.”

It is therefore important to identify some of the more successful methodologies for learning, promote their use, and measure their effectiveness against the framework. This is an illustrative, not exhaustive, list of quality programs at various education levels: kindergarten to 12th grade, undergraduate, and graduate to postdoctorate.

State-of-the-art education methodologies will be used as a guide to discriminate between good, better, and best proposals and offer prospective responders some insight into what the Task Force believes are state-of-the-art methods for teaching and learning.

### Kindergarten to 12

The **Mathematics and Science Partnership (MSP) Program** (<http://www.ed.gov/programs/matsci/index.html>) is intended to increase the academic achievement of students in mathematics and science by enhancing the content knowledge and teaching skills of classroom teachers. Partnerships between high-need school districts and the STEM faculty in institutions of higher education are at the core of these improvement efforts. Other partners may include state education agencies, public charter schools or other public schools, businesses, and nonprofit or for-profit organizations concerned with mathematics and science education.

In the **GK-12 Program**, a partnership is established between an Institution of Higher Learning (IHL) and a K–12 school system. After considerable preparation, meetings, etc., graduate students come into the classrooms in a collaborative manner to work with teachers and K–12 students. In this situation, all

participants collaborate inside and outside the classroom to facilitate the learning experience for all, but mainly for the K–12 students. All indication from third-party assessments is that this methodology is successful. It has been a functioning program for 7 years. For example, the National Science Foundation sponsors a University of Texas-Austin Environmental Science Institute Program (<http://www.esi.utexas.edu/gk12/>) that partners graduate students in the sciences with K–12 teachers in Texas to enhance science education through new classroom activities, workshops, and field projects. The 3-year project provides support for 10 graduate fellows each year to serve as resources for K–12 science students and teachers. The program emphasizes collaboration in K–12 classrooms and in field projects on Texas watersheds, estuaries, and ocean-going vessels.

### Undergraduate Student Research Program

The **NASA Undergraduate Student Research Project** provides research experiences to college (rising) juniors and seniors. It provides hands-on, mentored research experiences at NASA Centers, encourages and facilitates STEM student interest in professional opportunities with the aerospace community. It offers a 10–15 week research internship at a participating NASA Center.

### Graduate to Post Doctoral

The **Integrative Graduate Education and Research Traineeships (IGERT)** Program has been developed to meet the challenges of educating U.S. Ph.D. scientists and engineers who will pursue careers in research and education with the interdisciplinary backgrounds; deep knowledge in chosen disciplines; and the technical, professional, and personal skills to become, in their own careers, leaders and creative agents for change. The program is intended to catalyze a cultural change in graduate education for students, faculty, and institutions by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is also intended to facilitate diversity in student participation and preparation and to contribute to the development of a diverse, globally engaged science and engineering workforce. IGERT focuses on the need for establishing inter-/multi-disciplinary units centered around complex problems. Thus, it is reasonable to mix

very disparate disciplines together to accomplish a broad perspective. The program has been in place for 8 years and a third-party review established the excellence of this approach.

## INNOVATIVE TECHNOLOGIES

Powerful technologies are on the horizon that will enable new learning environments using simulations, visualizations, immersion, online game playing, intelligent tutors, learner networking, e-Professional Development (e-PD), digitized building blocks of content, and more. These capabilities are creating rich and compelling learning opportunities that meet the needs of individual learners. It is incumbent on the aerospace community to work to develop new methods of making its exciting discoveries and valuable resources available to students, educators, and researchers.

In the future, learning will be on demand. Students, educators, researchers, and the public will be able to receive what they need, when they need it, and where or how they want it (Brazell, Kim and Starbuck, 2004). The aerospace community is working toward this education future, developing new methods for making its exciting discoveries and valuable resources available to students, educators, researchers, and the public.

NASA Learning Technologies is currently developing a prototype game in collaboration with the Department of Defense team that developed the *America's Army* game and the game company Virtual Heroes. Their proof of concept will be based partly on the NASA International Space Station to demonstrate that a commercial-quality computer game can facilitate STEM learning and be NASA-mission focused. The prototype will be completed in 2007. In the same year, NASA is releasing a solicitation to develop another STEM- and NASA-based online game and learning environment.

Studies and after-school reports from children reveal that normal classroom activities are often neither engaging nor challenging (Quinn, 2005). Part of the problem is that teaching is still commonly done as it was more than a hundred years ago, with a teacher lecturing or assigning worksheets to students who sit at their desks, working alone on a task they may have little interest in. By contrast, outside the classroom, the same kids actively learn many things using computers in various guises

and applications such as instant messaging, podcasts, googling, wikis, and video games. Characteristics of all these out-of-school learning experiences are that students choose them, devote immense amounts of time to them, and are actively involved, often creating information while interacting with friends (Gee, 2003). Classroom instruction, by comparison, is often passive, devoid of choices, and lacking in interactivity (Gagne, 1972).

Nearly all children (92 percent) ages 2 through 17 engage in playing video games (ESA, 2006). E. S. Simpson (2005) reports in "What teachers need to know about the videogame generation" that game playing is not restricted just to boys either; 58 percent of families with only female children also own videogames. The most popular games are not "shoot-em ups," but role-playing games (RPGs); *The Sims*, an RPG, is the best-selling computer game ever. RPGs are compelling and require intense learning, and the learning can be applied almost immediately with immediate rewards for success in the forms of higher scores, progression to the next level, and bragging rights.

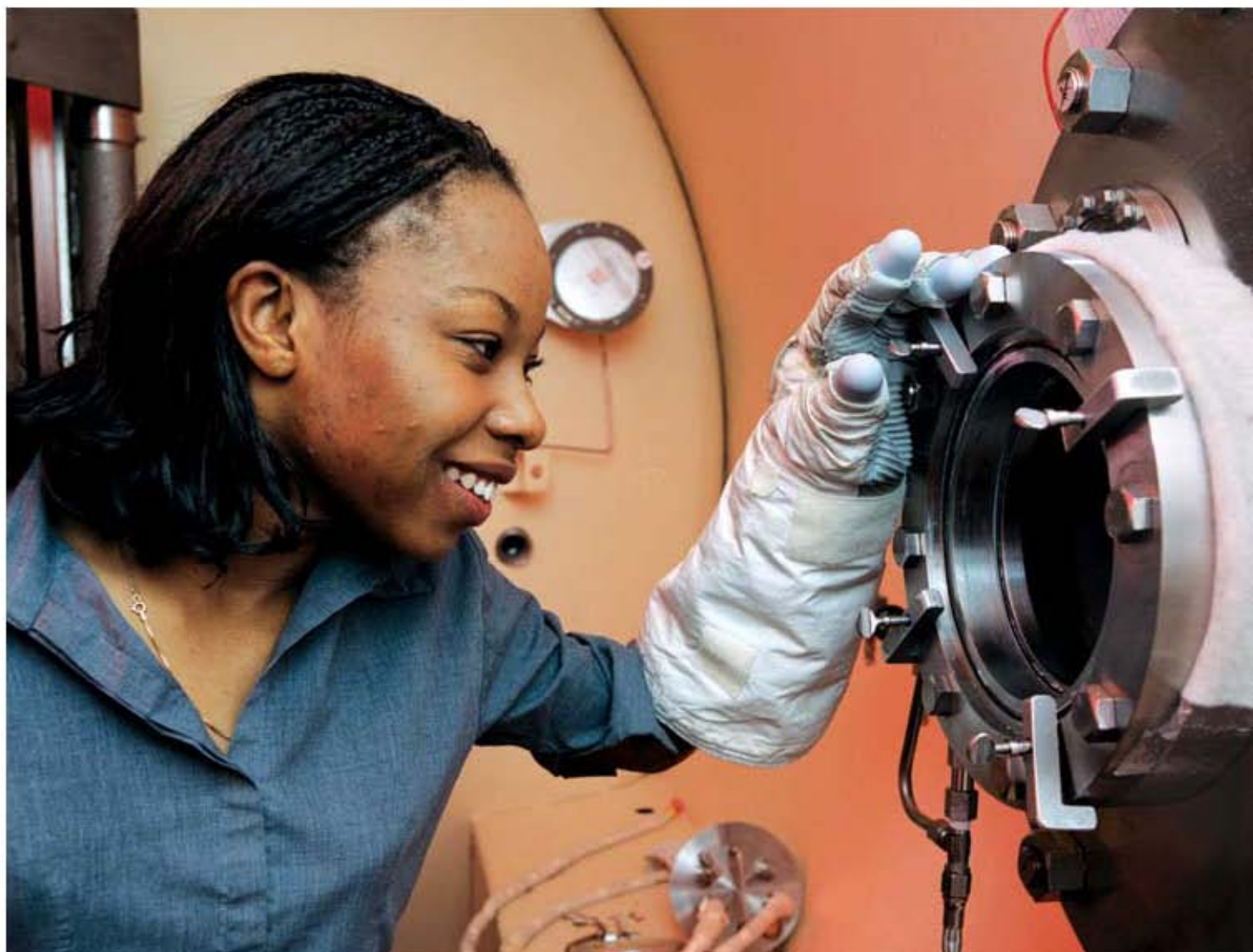
Videogames can help students become inspired by and understand the interrelated complexities of space travel and exploration. The United States has established the goal of returning humans to the Moon by 2018, establishing a base as the first step toward permanent habitation and as a training ground for later human exploration of Mars. Unfortunately, these laudable goals are jeopardized by a growing shortage of engineers and scientists (National Academy of Sciences, 2005). Worse than the present shortages is the statistic that fewer students are pursuing the math and science courses in high school that are necessary to prepare them for STEM majors in college. The aerospace community is now considering the use of videogames and other innovative approaches to inspire kids and to focus their academic interests on space and the adventure of solving the problems involved with moving humans to the Moon and beyond.

Rapid advances in technology have forced society to rethink its practices in every discipline and field, and education is no exception (Wolf and Perron, 2003). Search engines like Google and personal technologies like iPods and cell phones have made information highly accessible to anyone, anytime, and just about anywhere. We have become ravenous consumers of knowledge, limited only by our network access in any given location.

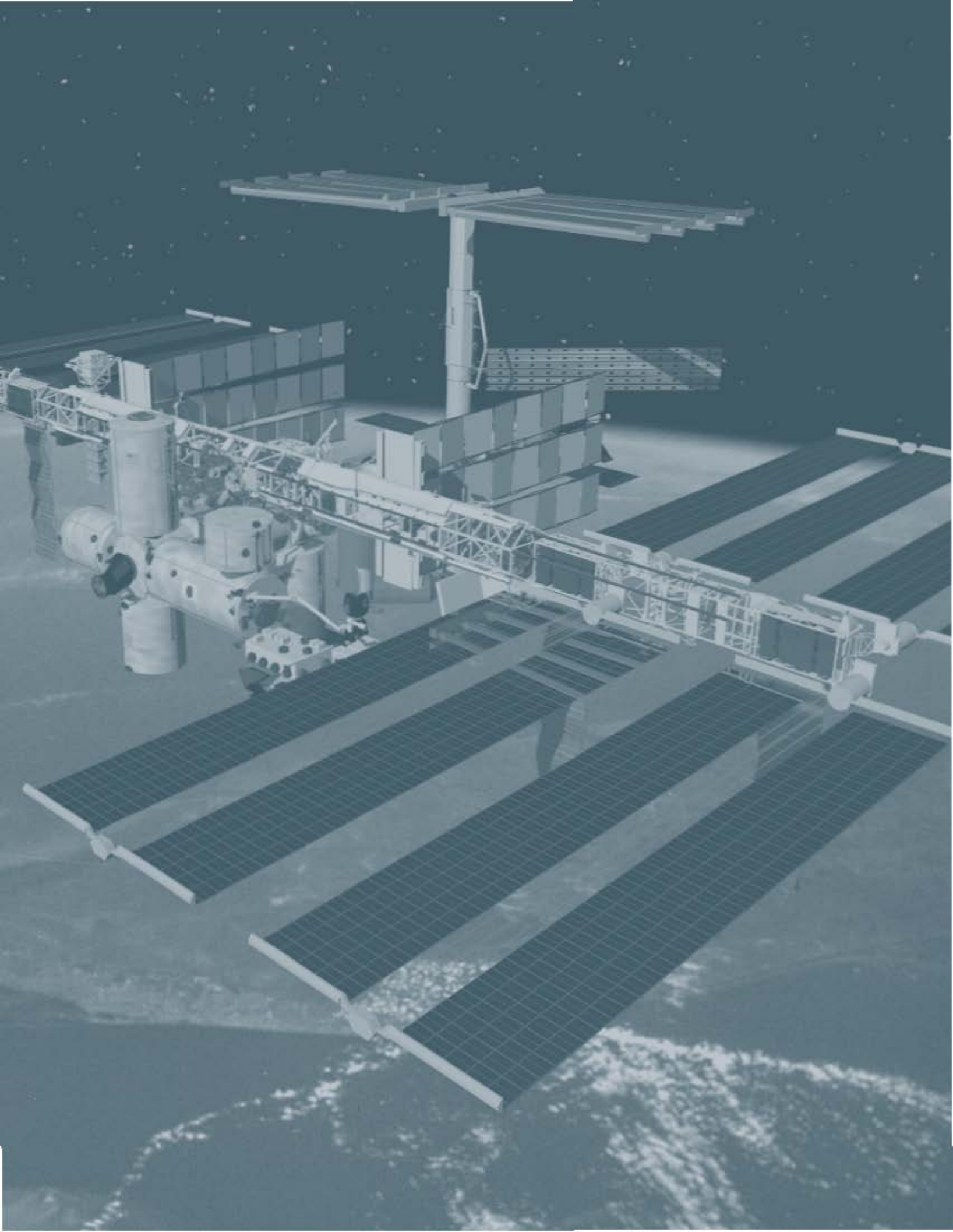
As we progress towards a more digitized world, there are important implications for the field of education. No longer are paper-based drills and static pages of information enough to sustain or engage students. A new type of learner is emerging, one who has grown up immersed in a computerized society and who expects more from education than did previous generations (Gee, 2003). This Net-generation learner is accustomed to accessing information immediately and finding answers to questions at the click of a mouse (Wood, 2004). In this new, high-tech world, much learning takes place outside of the traditional classroom through a variety of resources, and students are continuously bombarded with new bits of information. As a result, the line between formal and informal, out-of-school education is fading. A new “blended” learning approach is evolving, an approach

that uses technology to facilitate self-regulation, customization, and on-demand learning paths.

Technologies that bring information to the individual, such as cell phones and iPods, as well as technologies that promote social collaboration, like wikis, blogs, or even online games, need to be explored to determine how effective they can be in enhancing the learning process. The Project must explore different applications of new technologies to identify the most innovative and effective uses. The Project should also identify processes to develop educational content that may be enhanced by using new technologies. NASA eEducation is researching and developing the infrastructure to provide the new learners of the 21st century with the kinds of tools they experience recreationally within a NASA and STEM learning context.









## Support Infrastructures

### COMMUNICATIONS PLANNING

A communication plan will help publicize and highlight various media and outreach opportunities for ISS National Laboratory education projects. The plan will target the education and STEM media, their communities, the general public, and, when necessary, primary stakeholders and industry. The plan will include opportunities to:

- Measure impact and goals and objectives regarding public and media engagement;
- Engage formal and informal opportunities to highlight the ISS National Laboratory;

- Use toolkits and other outreach resources to engage the informal and formal education communities, the various media outlets and nontraditional media outlets; and
- Reach targeted audiences and promote the ISS National Laboratory.

The NASA Headquarters Office of Public Affairs, as appropriate, will:

- Issue media advisories and press releases inviting media, stakeholders, and the public to various events,

Sections broken into specific grade levels

Specific resources for each grade level

- HOMEWORK HELP
- INTERNET RESOURCES
- MULTIMEDIA RESOURCES
- LEARNING OPPORTUNITIES
- CAREER INFORMATION
- CONTACTS FOR STUDENTS



Figure 5. The NASA Education Web Site

conferences, and programs regarding the ISS National Laboratory;

- Look for opportunities to provide feature stories involving the ISS National Laboratory to newspapers, trade magazines, weekly magazines, local and regional media outlets, and public service outlets/announcements;
- Work with NASA Centers to help promote the ISS National Laboratory Project in the Centers' respective regions; and
- Collaborate with other Federal agencies' public affairs and outreach offices, industry, education forums, trade and consumer publications, media, and other stakeholders to reach the general public.

NASA will use NASA TV and the NASA Web site to help promote and highlight the ISS National Laboratory with feature stories, video files, and, when at all possible, live shots with various NASA and other Federal government experts. The expansion of NASA TV with an education stream is an unexplored opportunity. Text

messages, blogs, instant messaging, Myspace.com, and Youtube.com are just a few examples of mechanisms to be explored.

The NASA Education Web site (Figure 5, previous page) will also be used to extend the outreach of ISS-sponsored education modules, new support material, teaching and research opportunities, scholarships, and internships to the education community.

## PARTNERSHIPS AND COLLABORATIONS

### Overview

Extensive education efforts to inspire the next generation of explorers and reach new segments of the population, though praiseworthy, have not succeeded. NASA's education partnership strategy (Figure 6) now includes a targeted effort to develop new linkages with the education community, Federal agencies, and the corporate/nonprofit communities, resulting in improved science, technology, engineering, and mathematics education at

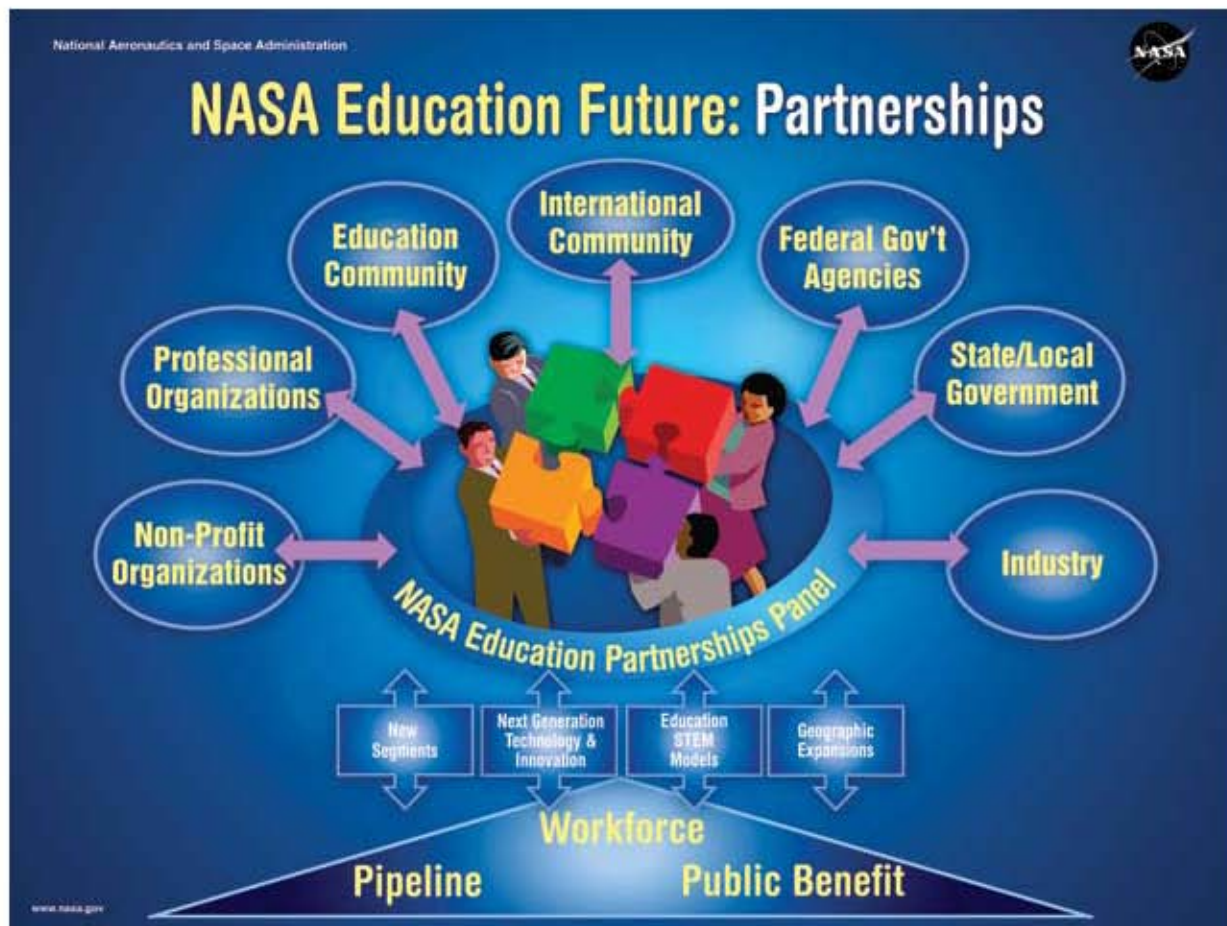


Figure 6. NASA's Education Partnership Strategy



all levels. Of keen interest are relationships with key media outlets and the emerging technology sectors. Each year, students enter school with new technologies, new media sources, and new ways they use technology in their lives. When considering the changing demographics of America, the need for new partnerships becomes apparent. The top radio stations in the five largest markets are Spanish-speaking and support major community awareness events and activities. The largest radio broadcasting company that primarily targets African-American and urban listeners reaches 14 million listeners per week.

Partnerships and alliances with national, State, and local education associations—representing teachers, faculty, and administrators who are knowledgeable about school curricula and standards—guide elementary, secondary, and post-secondary program development and implementation. National, State, and local associations, organizations, and institutions—which are knowledgeable about the needs and capabilities of underrepresented and underserved populations—guide all program development and implementation. Networks of informal education organizations—which are knowledgeable about the comprehensive missions of museums, science centers, and community-based groups—help shape public STEM literacy efforts. Partnerships with Federal agencies promote alignment with national STEM priorities; partnerships with State and local entities enhance alignment with State and local agendas; and partner-

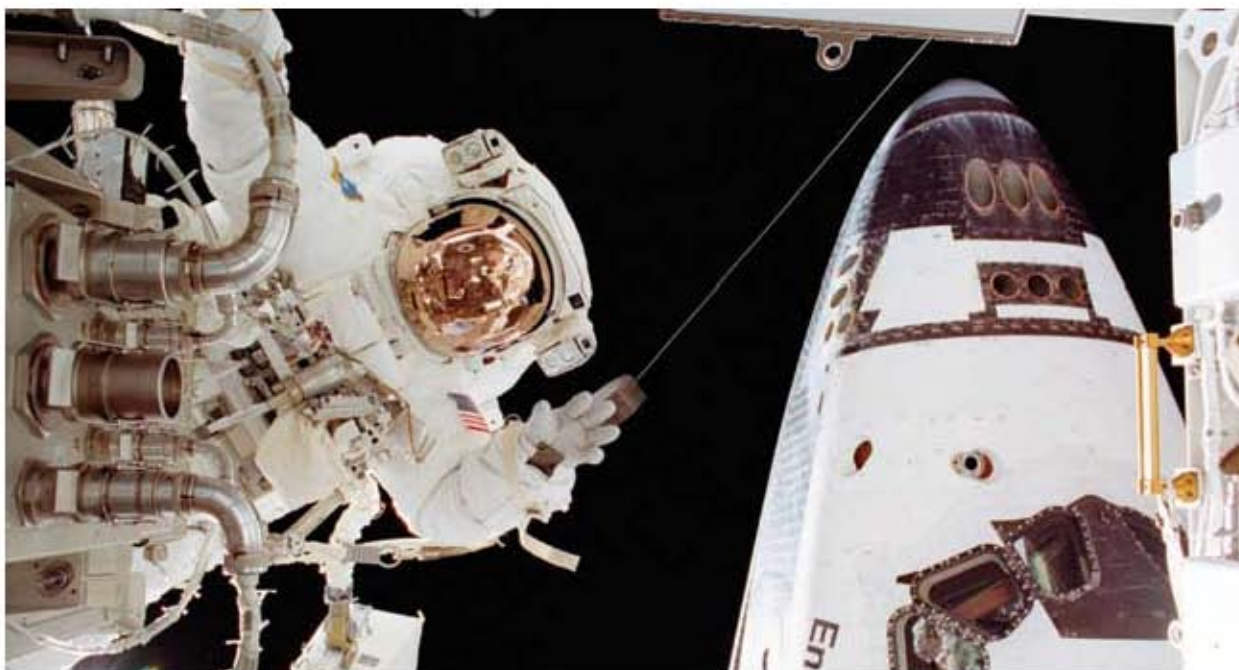
ships with business and industry ensure alignment with national human capital priorities.

Partnerships and alliances multiply the impact of NASA's education programs by leveraging knowledge, identifying additional target audiences and organizations, and sharing program resources.

### Examples of Established Partnerships

The Partnership Opportunity Chart (figure 7, next page) is illustrative of the kinds of alliances that exist. The opportunities for partnering are immeasurable. All partners share the same goals to inspire the Nation's youth to pursue careers in STEM and to improve scientific and technological literacy. Previous experience shows that exciting and compelling space programs ignite a yearning in our children to explore the universe. The Task Force, therefore, encourages strategic partnerships and alliances that fully utilize NASA content, people, and facilities in order to improve STEM education and thereby increase the supply of well-trained STEM workers.

Partnerships and collaborations incorporate the strengths of each partner to meet the education objective. These mutually beneficial partnerships help accomplish the Nation's education goals. Specific roles and responsibilities for each party are finalized via Space Act agreements. The Task Force looks forward to ongoing discussions with prospective partners.



**Figure 7. Partnership Opportunity Chart**

PARTNERSHIP OPPORTUNITIES	EXAMPLES CORPORATE/NONPROFIT PARTNERSHIPS
Professional Development for Teachers Invite teachers to attend short or long-term training sessions	NASA's Student Launch Initiative (SLI) project invites teachers and students to attend training in rocketry. The project is now operated in partnership with the Team America Rocketry Challenge (TARC), sponsored by the Aerospace Industries Association and the National Association of Rocketry.
Sponsoring Conferences and Workshops Sponsor teachers at STEM conferences and workshops	The National Science Teachers Association (NSTA), the National Council of Teachers of Mathematics (NCTM), and the International Technology Education Association (ITEA) provide lectures at their conferences to enhance STEM teacher knowledge.
Fellowships and Scholarships Sponsor scholarship and internships programs in STEM	Boeing provided residential Summer High School Apprenticeship Research Program (SHARP) students a mentored-research experience. Boeing also offered these students scholarships and other summer job experiences.
Products Activity kits, traveling exhibits, etc.	NASA and Girl Scouts USA (GSUSA) have partnered to develop products, curriculum, and training to GSUSA trainers.  NASA and the National Council of Teachers of Mathematics partnered to create the <i>Mission Mathematics</i> book series for students in Pre-K–2, 3–5, 6–8, and 9–12 grade bands.  NASA and the Geographic Education National Implementation Project (GENIP) partnered to create the Mission Geography (MG). MG created curriculum-support materials that link the content, skills, and perspectives of <i>Geography for Life: The National Geography Standards</i> with the missions, research, and science of NASA.
Programs with Content Sponsoring/administering events with content (courses, camps)	FMA Live is a traveling show on physics, sponsored by Honeywell and developed in partnership with NASA. The show travels to schools and public venues.
Delivery and Dissemination of Content Effectively deliver content to mega-populations	NASA and OfficeMax, Inc. have partnered to get Agency printed materials into the hands of students educators and the public quickly and easily. Materials can be printed at the closest OfficeMax store at a savings of up to 50 percent.  Public Broadcasting System (PBS) has entered into numerous partnerships over the years, including NOVA Origins (sponsored by the Office of Space Science). <a href="http://www.pbs.org/wgbh/nova/origins/">http://www.pbs.org/wgbh/nova/origins/</a>  NASA provided access to video from the Moon, as well as technical consultation for the film entitled <i>IMAX Magnificent Desolation: Walking on the Moon 3-D</i> .
Facilities/Equipment In-kind donations of equipment, facilities, etc.	Zero-Gravity Corporation conducts weightless flights to help share the experience of space flight with the general public, especially those educators who are developing our next generation of explorers.
Internship On-the-job training	National Space Society is launching, conducting, and managing a program to enhance the availability of internship opportunities among its members so as to increase the number and proficiency of students, especially minorities and women, entering aerospace careers.  The Triangle Coalition for Science and Technology Education works with the Department of Energy in creating Washington-based internships dealing with STEM education.
Mentorship Motivating/encouraging students to excel	Dupont USA employees serve as judges, role models, and mentors to the students who are interviewed during the International Science and Engineering Fair (ISEF). Dupont also provides awards to students who are noncitizens, which provides a great balance for NASA, who can only give an Honorable Mention Award to noncitizens.
Curriculum Development Produce curriculum for education activities	The Center to Advance the Teaching of Technology & Science (CATTS) is a consortium of 12 states working together to produce curriculum based on STEM standards.



## Costs and Cost Offsets

Development and operation of an education payload in the ISS National Laboratory Project can cost from zero to millions of dollars, depending largely on the amount of engineering required to develop the payload. Projects that do not require unique equipment can be realized much more quickly and economically than projects that use complex, sophisticated experiment apparatus. The cost for typical projects that do not require specialized equipment on board the ISS is expected to be below \$100,000. This level of funding could support the production of supplemental materials, engagement of consultants, and development of an on-orbit flight activity. Even these costs can be mitigated or shared.

### Potential Offsets

#### Bartering Ops Costs

Exchanging or negotiating the use of goods and services in return for other goods and services is widely practiced by NASA. NASA can help accomplish the education agenda through bartering. The education community could utilize United States bartered resources in exchange for needed goods and services. For example, bartering the use of internationally owned transport vehicles (i.e. Japanese HII Transfer Vehicle [HTV] from Japan, Progress from Russia, and the Automated Transfer Vehicle [ATV] from Europe) in exchange for international student participation on the ISS National Laboratory are “win-win” options that can be pursued. Transport to the Station is one of our highest-cost items and a major inhibitor of realizing student involvement in space. As such, the use of bartering to help accomplish education

goals is recommended. Since there are 16 countries contributing to the ISS, there should exist ample opportunities for bartering.

#### NASA On-Board Operations and Maintenance (O&M) Cost

The ISS Program Office covers ISS National Laboratory Project costs for operations and maintenance.

#### Utilization of NASA Astronauts

Involvement of the ISS crew in education projects is a centerpiece of the ISS National Laboratory concept. As the ISS National Laboratory matures, it is anticipated that a portion of the U.S. crew time will be devoted to education activities. This crew time will be available at no cost to the user. In the nearer term, as the ISS National Laboratory begins to identify and organize projects from the three sectors (academia, government, and industry), crew resources will be allocated in response to the need.

### Anticipated Costs

#### Costs for Development and Operations of a Satchel-like Experiment

Student Experiment Satchels are safe, multi-experiment carriers that could be placed anywhere in the ISS. Although this program has been discontinued, a similar capability would be valuable to education. There is a high educational return on investment and increased student-to-dollar ratio with use of multi-experiment carriers such as the Satchel. Historical costs for the small experiments that reside in the Satchel range from a few hundred to several thousand dollars. Students have had no difficulties raising funds to



build experiments. Cost drivers will include safety verification for unique experiment materials and development of complex experimental instrumentation.

### **Costs for Development and Operation of a Project like the Get-Away-Special**

Experiment containers similar in type to the discontinued NASA Get-Away-Special (GAS) canisters (which were largely autonomous, had simple data and control interfaces to the vehicle, and required low amounts of crew time) have been built by university students with budgets of a few tens of thousand dollars. Additional start-up costs would be required for developing standard canisters and funding support personnel for post-2010 launch vehicles. The GAS canisters flew on the Shuttle as ballast; therefore, they did not compete for mass with other payloads. Perhaps similar situations could exist for some post-2010 launch vehicles.

### **Costs for Payload Flight Qualification and Integration**

Education projects that use unique in-flight equipment must meet or exceed NASA's safety and integration requirements. Projects must complete NASA's payload integration process to verify that the flight equipment will operate as specified on orbit and that the crew understands the operation protocol and is trained to operate the equipment where required. Safety review and payload integration activities are services provided to users by the ISS Payload Office. However, users are expected to support these processes by participating in

all reviews and providing required payload engineering data, training models of equipment, and flight articles in a timely manner. It can be difficult for inexperienced users to navigate the payload integration process. Based on the experience of other small flight projects, a flight payload project should anticipate having one full-time integration engineer for the duration of the project.

### **Payload Operations Support**

The cost for Payload Operations Support, i.e., ground support resources to operate a payload, has been estimated to be approximately \$50,000, but may vary depending on the complexity of the payload.

### **Transportation Costs**

Transportation costs to the International Space Station will be borne by the user. In the next decade, a number of launch services providers are expected to be available, both domestic and international. NASA intends to stimulate commercial cargo and crew transportation in low-Earth orbit, with the goal of achieving reliable, cost-effective space access in a market-driven environment with the Commercial Orbital Transportation Services (COTS) program. While the extent of NASA's role in brokering these services is still under discussion, at a minimum NASA will help ISS National Laboratory users locate qualified launch service providers. Until a competitive market environment exists for commercial services to the ISS, launch costs for equipment required by education projects is likely to remain around \$10,000 per pound.



## **In Conclusion**

As the United States' segment of the International Space Station becomes more available to the educational community post 2010, the Task Force will move forward with this concept of operations. The Task Force will take advantage of this unique national laboratory by utilizing current research and best practices in STEM education, drawing upon the expertise of current educators and national educational organizations, building from past educational payloads and technologies, and partnering with Federal agencies to the extent possible under future funding profiles. To date, the ISS has reached over 33 million students, as profiled in *Inspiring the Next Generation: Student Experiments and Educational Activities on the International Space Station, 2000–2006*, authored by Donald A. Thomas and Julie A. Robinson. With the involvement and leadership of the Task Force agencies in the next phase of ISS-based education projects, the goal is to reach millions more, thereby increasing interest in STEM fields and space exploration.



## Appendix A

### U.S. LABORATORY ACCOMMODATIONS

#### Research Modules

ISS research requiring pressurized conditions will be conducted primarily in the following:

- The U.S. Laboratory, Destiny
- The European Columbus Module
- The Japanese Experiment Module, Kibo
- Designs and plans for the Russian Space Agency research modules are in the works.

Like the ISS interior, all of the research modules have a “shirt-sleeve” environment, with an oxygen-nitrogen atmosphere and temperature and humidity conditions similar to Earth-bound laboratories. Experiments within the research modules have access to power, cooling, communication, vacuum, exhaust, gaseous nitrogen, and microgravity measurement resources.

The U.S. Laboratory  
Module (Destiny)



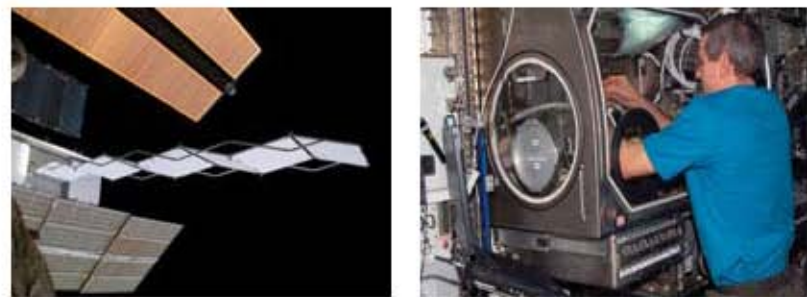
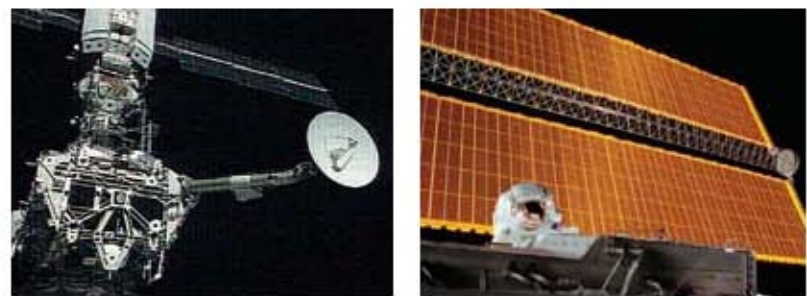
The European Columbus  
Research Laboratory  
Module



The Japanese  
Experiment Module  
(JEM)/Kibo



# Utilization Resources Post-Assembly



RESOURCESU.S. SHARED

[1] Research usage shared with system operations

# Physical Internal Accommodations Post-Assembly

INTERNATIONAL PRESSURIZED SITESRESEARCH RACK SITESSTATION-WIDEU.S. SHARED



Total3424



## INTERNAL RESEARCH ACCOMMODATIONS

### International Standard Payload Racks

Within the U.S., European and Japanese laboratory modules, the internal space allocated for payloads is configured around a system of uniformly sized equipment racks called International Standard Payload Racks (ISPRs). These racks, approximately the size of a large refrigerator, are designed to be extremely versatile for the type and configuration of equipment they can accommodate. The backs of the ISPRs have a radius of curvature just slightly less than the modules to efficiently fill all available space. The resulting module cross-sectional geometry has the racks arranged in quadrants around an interior workspace with a square cross-section. The workspace is in turn lined with racks along all four “walls” with the number of racks depending on the length of the module.

To support efficient integration and interchangeability of payload hardware and to maximize joint research among investigators, the ISS Program has adopted the ISPR. ISPR slots for payloads on the ISS provide a common set of interfaces regardless of location. Nonstandard services are also provided at selected locations to support specific payload requirements.

Each NASA ISPR provides 1.6 cubic meters (55.5 cubic feet) of internal volume. The rack weighs 104 kilograms (230 lbs) and can accommodate an additional 700 kilograms (1,543 lbs) of payload equipment. The rack has internal mounting provisions to allow attachment of secondary structure. The ISPRs will be outfitted with a thin center post to accommodate sub-rack-sized payloads, such as the 48.3-centimeter (19-inch) Spacelab Standard Interface Rack (SIR) drawer or the Space Shuttle Middeck Locker. Utility pass-through ports are located on each side to allow cables to be run between racks. Module attachment points are provided at the top of the rack and via pivot points at the bottom. The pivot points support installation and maintenance. Tracks on the exterior front posts allow mounting of payload equipment and laptop computers. Additional adapters on the ISPRs are provided for ground handling. Japan has developed an ISPR with interfaces and capabilities nearly identical to NASA’s.

Services available through ISPR interfaces include:

- Power
- Thermal Management
- Command and Data Handling
- Video
- Vacuum Exhaust System (Waste Gas)
- Vacuum Resource
- Nitrogen



*The Human Research Facility Rack 2 in preparation for flight to the International Space Station*

Low rate

High rate

Ethernet

Video

Nitrogen

Argon, carbon  
dioxide, helium

Moderate  
temperature

Flow rate

Low temperature

Flow rate

Venting

Vacuum resource



## EXPedite the Processing of Experiments to the Space Station (EXPRESS) Racks

In designing the ISS to accommodate sub-rack payloads, it became apparent that several advantages would be obtained if investigators building the equipment were provided with host racks with a standardized set of interfaces. Based on this, the EXPRESS rack concept was born.

The purpose of the EXPRESS rack is to allow quick and simple integration of payloads into the ISS.

The EXPRESS rack offers the following:

- Standard interfaces in an ISPR configuration for quick access to ISS resources;
- Structural support hardware;
- Power conversion and distribution equipment;
- Data and video equipment;
- Nitrogen and vacuum exhaust distribution hardware; and
- Thermal support equipment

An EXPRESS rack can be accommodated at any ISPR location on the ISS, but is typically installed in a 3-kilowatt ISPR location. The EXPRESS rack configuration shown accommodates eight Middeck Locker Equivalent (MLE)-payloads in two areas of four lockers each, and two 4-Panel Unit (PU) drawers. This layout can accommodate single or multiple MLE-style lockers.

MLE payloads are bolted to the EXPRESS rack backplate, which is attached to the rear posts of the ISPR. MLE payloads interface to resources via connection on the front face of the payload. Cooling is provided via passive radiation and heat exchange to the cabin environment, forced avionics air cooling via rear interfaces with the rack avionics air loop, or water cooling. Drawer payloads interface at the rear for power, data, and avionics air.

### Partner Module Interfaces

### Payload Interfaces

	Power Control Module SSPCM	Analog +/-
1553		RS-422
High Rate Video	Rack Interface Controller (RIC)	
Ethernet	Payload Ethernet Hub Gateway (PEHB)	
Nitrogen		Nitrogen
	AAA	

### Mass Capacity

### Power

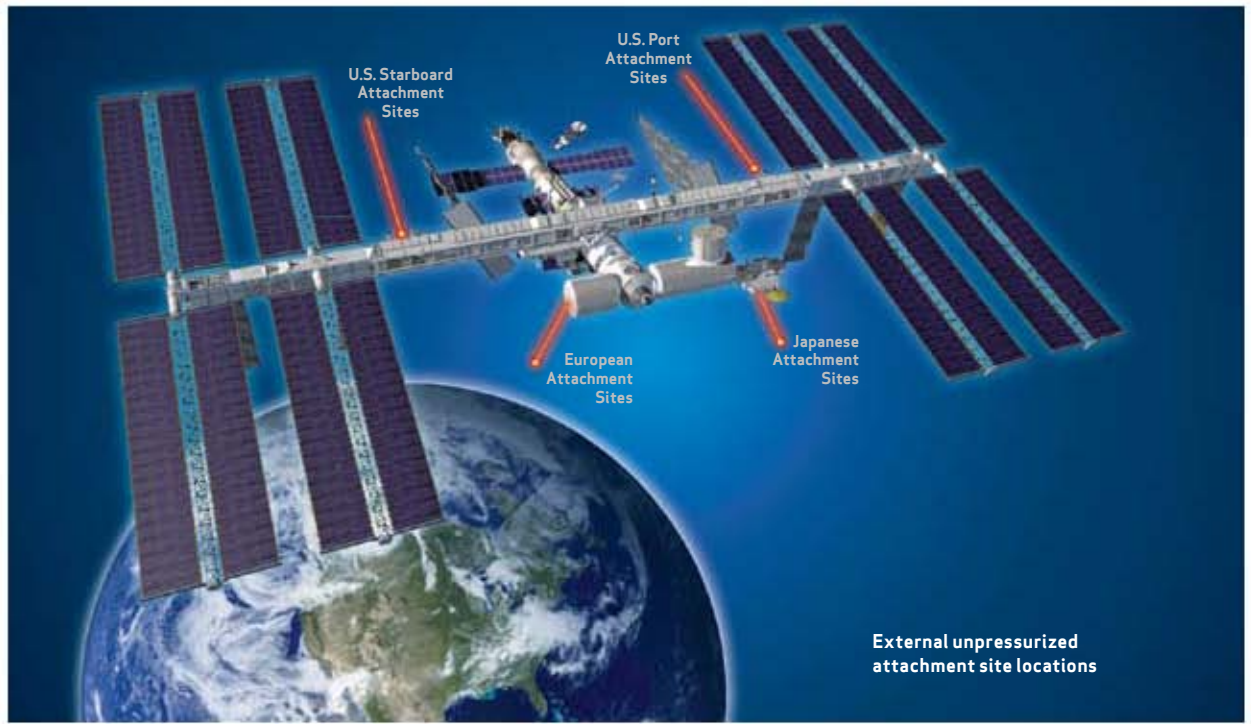
### Video

### Gases

### Thermal

### Vacuum

### Water



## External Site Payload Accommodations

Experiments that require exposure to the unpressurized environment may be mounted on the U.S. Truss, the Express Logistics Carrier (ELC), or the Japanese Exposed Facility (JEF), or the European Exposed Facility (EEF). These external mountings permit studies involving the natural vacuum of space or undisturbed cosmic radiation as well as weightlessness. Resources are available for a single payload occupying an entire Truss site or for payloads accommodated on the ELC, JEF, or EEF.

The external sites offer capabilities that include:

- Maximum payload height of 3.1 m (10 ft)
- Mass up to 4,990 kg (11,000 lbs)
- 3 kW of power at 113–126 Vdc
- 1 kW of power at 28 Vdc
- Data rate of less than 100 kbps via the 1,553 bus
- Data rate of 95 Mbps through the fiber optic high-rate data link
- 6 Mbps Ethernet

EXTERNAL UNPRESSURIZED ATTACHMENT SITES STATION-WIDE U.S. SHARED

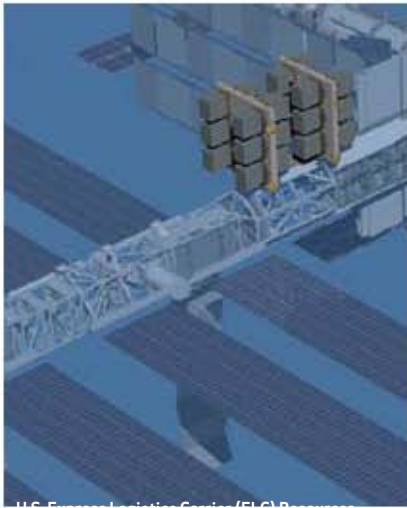
Total

24

17



## Capabilities of Physical External Accommodations Post-Assembly



US External Payload Carrier (EPC) Overview

Mass capacity  
Volume  
Power  
Low-rate data  
Thermal  
Local area network



IBM Blue Gene/L Supercomputer

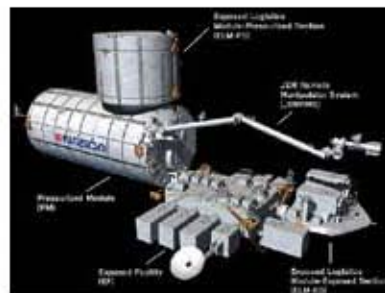
Mass capacity  
Volume  
Power  
Thermal  
Low-rate data  
High-rate data



European Columbus External Payload Carrier

Mass capacity  
Volume  
Power  
Thermal  
Low-rate data  
Medium-rate data

Mass capacity  
Volume  
Power  
Thermal  
Low-rate data  
Medium-rate data



Columbus External Mounting Locations





## Appendix B

### DEFINITIONS

#### Assessment

An assembly of information that is subsequently analyzed. A “weighing” of the understanding and command of knowledge that a person has developed. A systematic process of defining, selecting, designing, collecting, analyzing, interpreting, and using information to make inferences about the learning and development of students.

#### Automated Transfer Vehicle (ATV)



European Space Agency's (ESA) Automated Transfer Vehicle will be one of the indispensable ISS supply spaceships. The first ATV launched will be called the Jules Verne. Every 12 months

or so, the ATV will haul 7.5 tons of cargo from its launch site in French Guiana atop an Ariane-5 rocket to the ISS.

#### Basil Seeds In Space



As many as two million students will grow seeds exposed to space to compare with control seeds that remain on the ground. Materials International Space Station Experiment (MISSE) is a suitcase-sized, materials-

exposure facility mounted externally on the ISS and is designed to evaluate the durability of materials and coating exposed to the extreme environment of space (atomic oxygen, radiation, vacuum, thermal cycling, micrometeorites, etc.). A package of 8 million basil seeds from the Park Seed is scheduled to fly to the ISS and will remain in space for approximately one year, subjecting the seeds to microgravity, vacuum, radiation, and thermal cycling. After the seeds are returned to Earth (following a one-year period mounted to the outside of ISS), they will be packaged and made available to schoolchildren, along with packs of

“control” seeds that remained on Earth and were not exposed to the space environment. Students will grow the “space” seeds and “ground” seeds side by side to look for differences resulting from space exposure. This activity is modeled closely after the successful tomato seeds student experiment “SEEDS” that flew on NASA's Long-Duration Exposure Facility in the 1980s. An astronaut installed an MISSE carrier on the outside of the Station during the STS-105 mission.

#### NASA Cooperative Education Programs

NASA Cooperative Education Programs are designed to combine academic studies with on-the-job training and experience and to give students an opportunity to work at a NASA Field Center while completing their education.

#### Commercial Orbital Transportation Services (COTS)

NASA's COTS program is intended to stimulate commercial cargo and crew transportation in low-Earth orbit, with the goal of achieving reliable, cost-effective space access in a market-driven environment. Two projects now underway are scheduled for initial proof-of-concept demonstration flights in 2008–2009, with a program goal of providing over 10,000 kilograms per year of cargo delivery capability to locations including the ISS. Commercial transportation services could be available as early as 2009–2010.

#### Curriculum

A bundle of logical and reinforcing information. A “path” through a set of knowledge that allows the learner to develop understanding of an intellectual domain. A course of study, a set of materials, and knowledge to be transmitted.

#### Data

Objective and validated information, usually collected systematically. Factual information organized for analysis or used for decisionmaking.



### Earth Knowledge Acquired by Middle School Students (EarthKAM)

EarthKAM is a NASA-sponsored education program that enables thousands of students to photograph and examine Earth from the unique perspective of space. Using the EarthKAM Web pages available at <http://earthkam.ucsd.edu/>, students control a special digital camera that is mounted in a window on the ISS. From this window, these students are able to photograph a wide range of beautiful and fascinating features on the surface of Earth. They are also able to investigate a wide range of topics such as deforestation, urbanization, volcanoes, river deltas, and pollution, to name a few. During an active EarthKAM session, middle school students select photographic targets linked to the curriculum of each school. Next, undergraduate students at the University of California, San Diego, integrate the requests from the schools at the Mission Operations Center and send a camera control file to the NASA Johnson Space Center (JSC) in Houston for uplink to the ISS. The resulting photographs of Earth are downlinked from the Station back to EarthKAM and are made available on the World Wide Web for viewing and study by participating classrooms and the general public.

### Educate

Focused education support that promotes learning among targeted populations. Education activities focus on student learners or pre-and in-service educators and are designed to develop and/or enhance specific STEM knowledge and skills using NASA resources.

### Educator Astronaut

Educator Astronauts are full-time NASA astronauts who have experience and skill in K-12 classroom education. Their role is to help lead NASA in the development of new ways to connect space exploration with the classroom



and to inspire the next generation of explorers. Educator Astronaut Barbara Morgan is scheduled to fly to the ISS on Shuttle flight STS-118 (13A.1) during Expedition 15. The theme for education activities on the flight will be habitats. Three Shuttle crewmembers and an ISS crewmember will demonstrate aspects of the Shuttle mission in building and resupplying the ISS. The crew will set up seeds and growth chambers and growth will be completed on the ISS after the Shuttle returns to Earth. Students will participate in their classrooms by using the same growth chambers and seeds. The curriculum will focus on aspects of the human habitat in the ISS and how that relates to habitats on Earth.

### Engage

Projects and activities that incorporate participant interaction with ISS content for the purpose of developing a deeper understanding.

### Employ

Projects and activities that target the development of individuals who are preparing for employment in disciplines needed to achieve the Nation's mission and goals. Through internships, fellowships, and other professional training, individuals acquire sufficient mastery of knowledge for employment with the Federal government, academia, industry, etc.

### Get-Away Specials (GAS)

GAS experiments are self-contained investigations enclosed within a canister, often with a power system that is activated by a crewmember. These active experiments have electromechanical systems that autonomously operate in space, collecting and storing data within the experiment. Flight data is retrieved after the experiment hardware is returned to the principle investigator. GAS experiments have included plant growth, flame/fire propagation, crystal growth, material mixing, and fluid dynamic investigations to name a few.



### High School Students United With NASA To Create Hardware (HUNCH)

More than 550 students at 20 schools are impacted by HUNCH, which reaches "at-risk" students in vocational education classes. Students in high school and middle school who are in career and technology classes study real flight hardware as they fabricate training hardware in this project. NASA provides materials and documentation and the teacher





provides direction to the students and a safe working environment. The goal of HUNCH is to inspire the next generation of explorers through hands-on application by fabricating products that will be used at NASA. Students are taught the mathematics and science that are involved with the fabrication of flight and training hardware. This training hardware is then used to prepare astronauts and ground support personnel for jobs on orbit. This hardware is used both at NASA Marshall Space Flight Center (MSFC) and NASA Johnson Space Center (JSC).

### HII Transfer Vehicle (HTV)



Japan is building an HII Transfer Vehicle that can perform additional logistics and resupply functions in the future.

### Information

Organized data, aggregated to inform the knowledge base on a given topic. It is that which reduces uncertainty.

### Inspire

Activities focused on promoting awareness of space among the public, primarily through informal education and outreach activities. This category is heavily supported by the outreach activities of multiple organizations. Inspire-level efforts are broad, with the goal of reaching a large number of people.

### Instruction

Instruction is a method of conveying information, usually pedagogically presented. A method of conveying and building knowledge, understanding, and insight.

### Knowledge

Aggregated and compiled information that describes phenomena and potentially allows phenomena to be predicted and sometimes controlled. Understanding acquired through study or experience.

### Payload

The carrying capacity of an aircraft or space vehicle, specifically scientific instruments or experiments.

### Professional Development

A process wherein an individual's knowledge is increased to accommodate specific goals. A process for deepening and continuing the growth of understanding of an intellectual domain, especially geared to enabling the individual to instruct others in that domain. It includes content, pedagogy, and pedagogical-content knowledge.

### Research

A process wherein facts, data, and information are gathered, evaluated, and assessed, and conclusions are derived in the context of knowledge that has already been established systematically and with a desire to eliminate competing explanations for phenomena. Any systematic investigation designed to develop or contribute to the knowledge base in a given domain.

### Satchel

Satchel experiments are self-contained “fly and compare” investigations. Students fly sample materials on the ISS. The materials are contained within approved NASA vials. Students retain “control” samples that are used for comparison upon return to Earth. Some student objectives are to determine which materials best withstand the rigors of space flight and are best suited for astronaut use. Past Satchel experiments have included items such as seeds, electrical components (chips, bulbs, and transistors), medicine, soil samples, and radiation-shielding investigations.



### Understanding

“The ability to represent concepts and situations in a way that is general; generative; connected to other representations; able to guide skill development; and important in reasoning, inference, and the development and transfer of skills” [Graeme Halford, Cognitive Theorist].



## Appendix C

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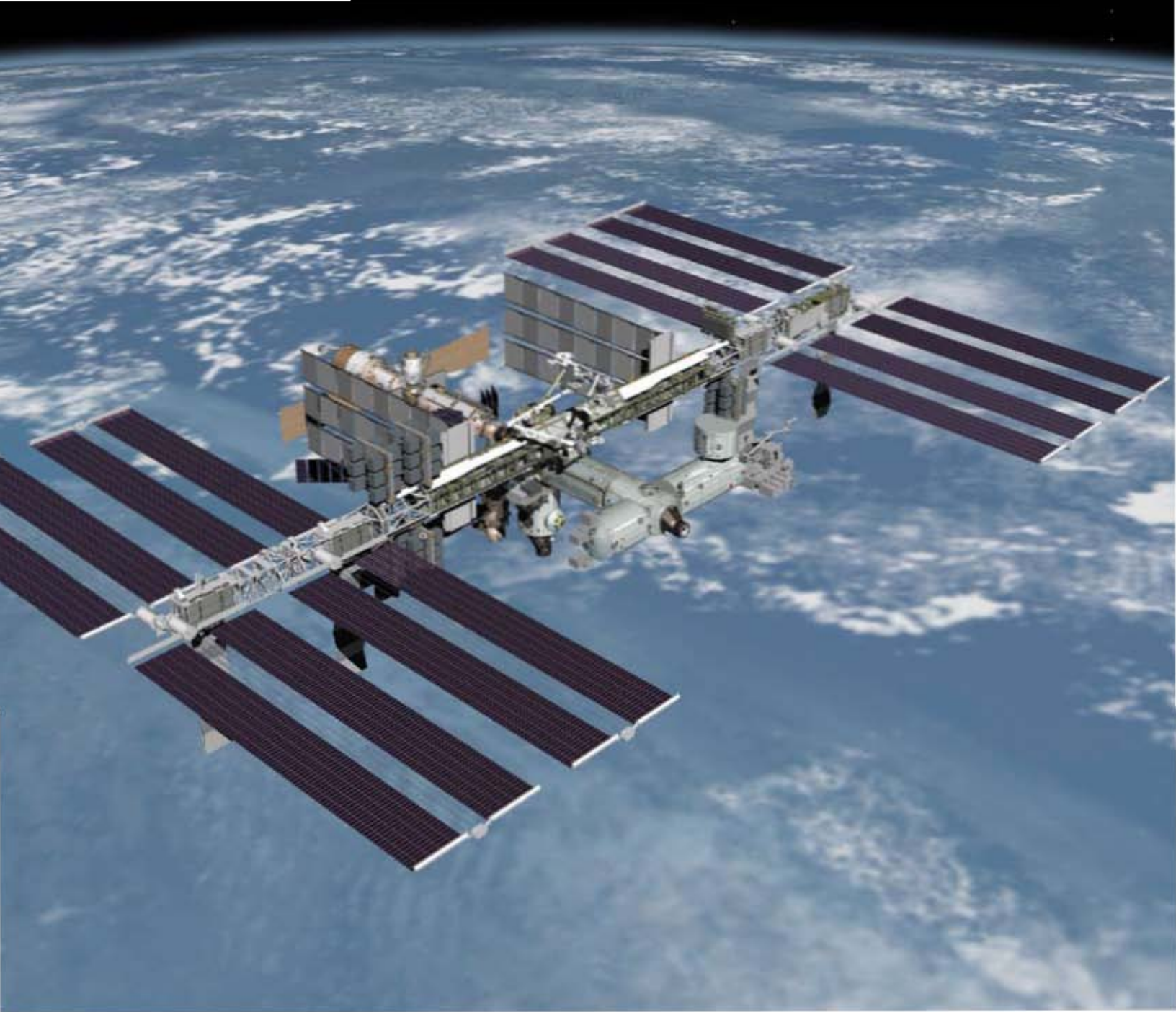
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## ACRONYMS

°C:	degrees Celsius	kW:	kilowatts
AAAS:	American Association for the Advancement of Science	lbm:	pounds mass
AASCU:	American Association of State Colleges and Universities	lbs:	pounds
AIAA:	American Institute of Aeronautics and Astronautics	LMA:	Lockheed Martin Academy
ACI:	American Competitiveness Initiative	Mbps:	megabits per second
ASTC:	Association of Science-Technology Centers	MG:	Mission Geography
ATV:	Automated Transfer Vehicle	MIL-STD:	Military Standard
CATTS:	Center to Advance the Teaching of Technology & Science	MISE:	Merck Institute for Science Education
CEF:	Columbus Exposed Facility	MISSE:	Materials International Space Station Experiment
COTS:	Commercial Orbital Transportation Services	MLE:	Middeck Locker Equivalent
EbD™:	Engineering by Design™	MSP:	Mathematics and Science Partnership
ELC:	Express Logistics Carrier Facility	NASA:	National Aeronautics and Space Administration
e-PD:	e-Professional Development	NASDCTE:	National Association of State Directors of Career and Technical Education
ESA:	European Space Agency	NCTM:	National Council of Teachers of Mathematics
EXPRESS:	EXpedite the Processing of Experiments to the Space Station	NOVA: (NOVA Origins)	Miniseries hosted by astrophysicist Neil de Grasse Tyson
FMA Live:	Name derived from Newton's law: force equals mass times acceleration (Touring show, sponsored by Honeywell)	NSF:	National Science Foundation
GAS:	Get-Away Special	NSTA:	National Science Teachers Association
GENIP:	Geographic Education National Implementation Project	NTSC:	National Science and Technology Council
GSE:	Graduate School of Education	O&M:	Operations and Maintenance
GSUSA:	Girl Scouts USA	PACE:	Protecting America's Competitive Edge
HTV:	HII Transfer Vehicle	PBS:	Public Broadcasting System
HUNCH:	High School Students United with NASA to Create Hardware	Penn STI:	Penn Science Teachers Institute
IECWG:	ISS Education Coordination Working Group	PLTW:	Project Lead the Way
IGERT:	Integrative Graduate Education and Research Traineeships	PU:	Panel Unit
IHL:	Institution of Higher Learning	RPGs:	role-playing games
ISEF:	International Science and Engineering Fair	RSA:	Russian Space Agency
ISPR(s):	International Standard Payload Rack(s)	scfm:	standard cubic feet per minute
ISS:	International Space Station	SGT:	Stinger Ghaffarian Technologies
ITEA:	International Technology Education Association	SHARP:	Summer High School Apprenticeship Research Program
JEF:	Japanese Exposed Facility	SIR:	Spacelab Standard Interface Rack
JEM:	Japanese Experiment Module	SLI:	Student Launch Initiative
kbps:	kilobits per second	STEM:	Science, Technology, Engineering, Mathematics
kg:	kilograms	TARC:	Team America Rocketry Challenge
		TIDE:	Technology, Innovation, Design, and Engineering
		UCF:	University of Central Florida
		VDC:	Volts Direct Current
		W:	Watts



## **NASA Education:**

Revolutionizing learning,  
one mind at a time.

# **Employ, Educate, Engage, and Inspire . . .**

the next generation of explorers  
and innovators.